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The process of atomisation of liquid fuels is of great importance in many combustion processes. It is not surprising, therefore, that the subject has attracted the attention of many research workers and although a great amount of work has been done, there still remain many unsolved problems in the field of fuel spray atomisation. It is not possible in this book to quote all the investigations carried out or to present all the available data, but the authors have succeeded very well in their task of sifting the information available and selecting what they consider to be the most useful results.

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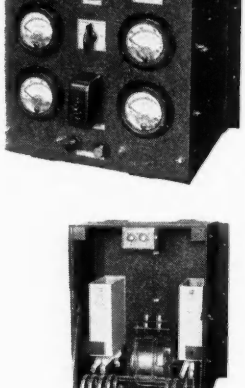

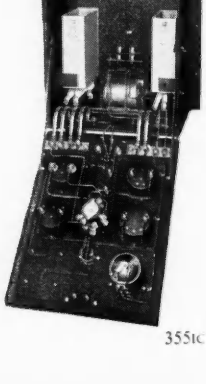

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All subscriptions, distribution and business communications to Jarrold & Sons Ltd, Norwich *Telephone* Norwich 25261
Subscription Rates Inland and Overseas 6 months 9s, 12 months 18s *U.S.A.* 6 months $1.50, 12 months $3
Advertisement Office Aldridge Press Ltd, 15 Charterhouse Street, EC1 *Telephone* Holborn 8655

AUGUST 1953 VOLUME XIV NUMBER 8

THE PROGRESS OF SCIENCE

THE FILM AND SCIENCE

In a recent lecture to members of the Royal Photographic Society Mr. John Maddison, who is a recognised authority on scientific films, reminded his audience that it was an interest in the scientific applications of photography that led to the birth of the cinema. Among the pioneers of cinematography was Thomas Edison, who saw the principal benefits of the new invention as being its use in scientific investigation. But in the years that followed, the commercial development of films as a medium of mass entertainment overshadowed the application of cinematography to the purposes of education and research. There has been, however, a good deal of progress in the latter direction, and though the scientific film has yet to find its way into the commercial cinema circuits to any significant extent, the use of the film medium by scientific workers in the universities, in industry, in teaching and in research, is now firmly established.

This year sees the tenth anniversary of the foundation of the Scientific Film Association, which owed its inception to the initiative of the Films Committee of the Association of Scientific Workers. This organisation, now almost universally called the SFA, is a voluntary grouping of organisations and individuals which is characteristically British. It resulted from the combination of producers of films with scientists, doctors and teachers interested in making or using films for scientific purposes.

From its inception, the SFA has sought to be a centre for the collection of information about British scientific films, and it has carried out this function very effectively. It has concentrated on the regular and systematic appraisal of films and on building up a full information service by means of catalogues and card indexes. Its first *Catalogue of Films of General Scientific Interest*, published in 1946, contained 580 titles. Other specialised lists and catalogues followed, the most recent of which are the revised *SFA Catalogue of Medical Films* and *List of Films for Training in Industry*. Catalogues of films on Chemistry and Economics are nearing completion, and a supplement to the Medical Catalogue is also in course of preparation.

In addition, the SFA has now undertaken the regular appraisal of new scientific films, and the results are published quarterly as a supplement (called "Scientific Film Review") to the monthly bulletin of the British Film Institute.

In the international sphere, the SFA collaborated with the French Institut de Cinématographie Scientifique to found—in 1947—the International Scientific Film Association (ISFA). This move has led to the organisation of regular international exchanges of information, meetings and publications dealing with the scientific film.

The two most important activities of ISFA have been its Annual Congress and Festival of Scientific Films, and the quarterly publication of the international review *Science and Film*. That journal was started in March 1952 and already circulates in some seventy countries; a supplement called *Research Film* is now published in German, French and English. There has been an ISFA Congress each year since 1947. The seventh congress is being held this year in London, and will take place in the National Film Theatre and the Royal Festival Hall next month.

So much for the international links which the SFA has helped to build. An important development in the SFA's domestic affairs occurred in recent months. The association itself has undergone reorganisation following negotiations with the Office of the Lord President of the Council and the British Film Institute.

The annual Government grant made to the SFA via the British Film Institute has been substantially increased. The SFA itself has become an incorporated company under those provisions of the Companies Act, 1948, which permit incorporation of non-profit-making bodies without share capital and limited by guarantee, and it is now governed by Articles of Association which greatly strengthen its structure and constitution.

The SFA now has a full-time general secretary (Mr. J. Stewart Cook, B.Sc.). Its Council of Management has been reconstituted and now consists of the three elected honorary officers (President, Vice-President and Treasurer) together with six other elected members and seven members appointed by the Lord President of the Council. As a result the Department of Scientific and Industrial Research, the Medical Research Council and the Agricultural Research Council are represented on the Council, which also includes a spokesman from industry.

These developments have, however, brought one difficulty. The incorporation of the SFA meant that the unincorporated association had to be formally wound up and the newly formed corporate association started afresh, with new membership: it will come as no surprise to students of voluntary organisations to be told that this has resulted in a temporary, but heavy, loss of members. The membership of the SFA has never been a mass membership although it has always been a very active membership, and the list of its corporate members—learned societies, professional institutions, scientific film societies, etc.—as set out in its last annual report is an impressive one and testifies eloquently to the reputation which the SFA has earned in its chosen sphere.

There must be many individuals and organisations, however, who would find it of real value to participate in the work of the SFA. In doing so, they could be assured that their support was being given to an organisation whose ideals, achievements and future programme deserve the full support of all interested in the subject of film and science.

WANTED: AN IDEAL INSECT REPELLENT

Many inquiries have been received from readers, asking for information as to what is the most efficient insect repellent yet discovered.

As with insecticides, repellents vary in effectiveness against different insect species. For example, dimethyl phthalate (DMP) is most effective against the American mosquito (*Anopheles quadrimaculatus*), indalone is most effective against the stable-fly (*Stomoxys*), while 2-ethyl-1 : 3 hexanediol ('Rutgers 612') is most effective against the mosquito that carries yellow fever (*Aedes aegypti*).

We can say, however, that DMP is persistent and effective in repelling a large number of species. It has certain properties which compel care in its application; for instance its solvent action on plastics and the smarting of eyelids and lips which it causes. Dibutyl phthalate is similar but slower in action, and has also been found useful against mites and leeches. DMP has been found useful against biting midges. One application of DMP cream can be effective for several hours.

Pyrethrins can be used at high concentrations as repellents, and during the war in the Middle East they were used in a cream base. They were found to be effective, for 4–6 hours, against two important species of mosquito, but their high cost and the possibility of allergic reactions in some people militate against large-scale use of pyrethrins as repellents in peace-time.

Among the older repellents, oil of citronella is one of the most effective; however, it was found during the war that certain creams containing this substance were effective for only two hours, after which they actually became attractive to mosquitoes, because of the base which was used! One old standard recipe (containing 2 oz. oil of citronella, 2 oz. eucalyptus oil, 4 drops carbolic acid) is still used and may prove quite useful, but is not likely to be as long-lasting as DMP, nor as effective.

Clearly, an 'ideal' repellent has not yet been found, and it is unlikely that one which is effective against all species of biting insects will ever be found. Furthermore, it is well known that individual behaviour of even insects implies that there will never be a repellent 100% effective against any one species, since there is always the 'suicidal' attacker which bites through anything!

Many people suffer extreme discomfort from insect bites: here a valuable remedy does exist in the form of an antihistamine preparation called Amphisan. We are assured by an impartial expert that this cream gives very speedy relief.

REINFORCED PLASTICS

One of the newest and most important materials of modern industry are the reinforced plastics, i.e. plastics of various kinds which have been strengthened by the incorporation of textiles like cotton or nylon; even more effective for certain special purposes are such fibrous materials as asbestos and fibre glass.

The particular qualities of the reinforced plastics vary according to the type of resins from which they are made, the manner in which the reinforcing material is assembled (whether for example as a mat of small fibres or in the form of a fabric woven from threads made from the fibres of the reinforcing material) and the way in which the reinforced plastic is finally moulded.

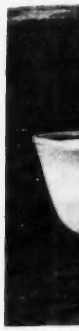
All reinforced plastics have, however, certain common qualities; they are corrosion-resistant and have excellent dimensional stability, while at the same time having an almost metal-like strength. They differ from metal in being more resilient, which makes them attractive to a manufacturer of car bodies: a mudguard, for example, made of reinforced plastic does not dent so easily as metal. They are also good electrical insulators.

A multitude of uses has been suggested for these new materials varying in range from railway rails (an experimental track has already been laid in the U.S.A.) to dies for metal-forming, but perhaps the three most often discussed, and indeed most immediately striking applications are their use for building car bodies, small boats and aeroplane wings.

It was in 1936 that Henry Ford the elder first swung a hammer at a plastic car body in order to demonstrate that its lightness was not incompatible with mechanical strength, but it is the progress in development of reinforced plastics during the last few years that brought the plastic car body into the realms of practical possibility.

At first these plastic car bodies used to be made as a single moulding, but present trends are towards the manufacture of interchangeable plastic sections. A car body of this type will weigh 100–200 lb.—which is very much lighter than its metal counterpart.

Plastic dinghies and small sailing boats are already



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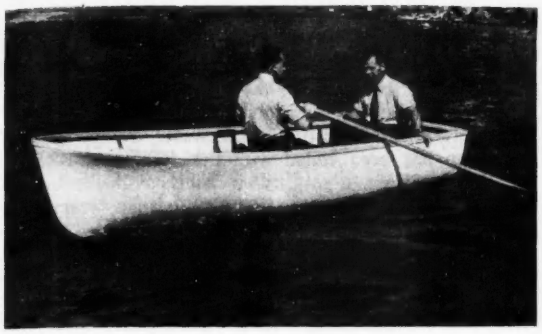

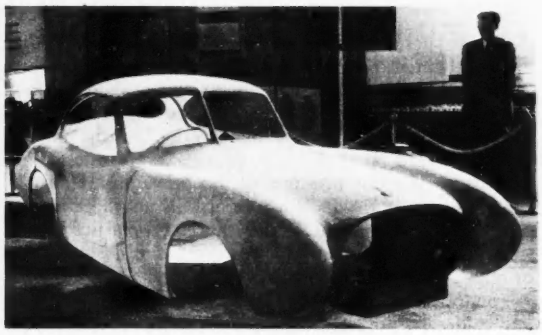

FIG. 1 (*left*). A dinghy of reinforced plastic. The suitability of this type of material for small-boat construction is being tested by the British Navy. FIG. 2 (*right*). A car body moulded in reinforced plastic—a polyester resin based on a glass-fibre fabric: it weighs just over 100 lb. (*Courtesy, "British Plastics".*)

available in this country. One Weymouth firm is making a 12-ft. dinghy and will soon have a 20-ft. boat in production. In this case the reinforcement used is fibre-glass cloth, which is cut into suitably shaped pieces and laid on a former, shaped to the inside of the hull. The hot synthetic resin is then applied to the outside with a spray so that the glass cloth becomes buried in the plastic, and a smooth even layer is built up on the outside. The plastic hull is now left to harden, after which it is removed from its former and built up into a complete boat. This seems to be quite a satisfactory method for the fabrication of the small motor-boat type of craft, but more highly mechanised techniques would have to be used for larger vessels. One advantage of plastic hulls is their resistance to the corrosive action of sea-water.

At this year's British Plastics Exhibition a 30-ft. moulded glider wing made of plastic material reinforced with asbestos was shown. Here it is the combination of lightness with stiffness that is important.

The difference between glass-fibre and asbestos as reinforcing materials lies partly in their relative costs—asbestos is the cheaper material—and partly in the qualities they give to the plastic. Asbestos-reinforced plastic is stiffer than glass-fibre reinforced plastic, but the latter has the better tensile strength.

While in this country the asbestos fibres are usually used in the form of a felt, or compressed mat of long individual fibres, glass-fibre is generally used in the form of a staple or continuous thread, made up of some 200 parallel fibres, which is woven in a variety of different ways to yield the reinforcing fabric. It is the *length* of the individual asbestos fibres which gives the asbestos-reinforced material its special mechanical properties; reinforcing with short fibres has little effect on the mechanical strength of the material. Similarly it is the weave that determines the mechanical properties of the glass-fibre reinforced plastic. The best stiffness results from a plain weave where the crossing thread goes over one of the vertical threads and then under the next and so on. The greatest strength and pliability is found when the reinforcing material is woven in the Eight Harness Satin Weave, in which the crossing thread crosses over seven threads before going under the eighth. Intermediate weaves imparting intermediate properties are the Basket Weave and the Crowfoot Weave. The practical importance of this lies in such factors as the relative mouldability of the resulting materials, or their porosity, or resilience. A reinforced plastic based on a plain weave cannot be moulded round corners, whereas one incorporating a Crowfoot Weave or Eight Harness Satin Weave can. On the other hand, the latter cannot be used where a porous material is required; for this purpose a plain weave is best.

At present the handling of both asbestos fibres (which may also on occasion be made into threads) and glass-fibres is bound by the conventions of the textile industry, and as Lord Halsbury suggested in his inaugural address to the British Plastics Convention held in London in June, this may well be a mistake.

FIG. 3. PLAIN CROWFOOT EIGHT HARNESS SATIN WEAVE

The plastics themselves and the techniques of moulding are closely interlinked. Great advances have recently been made in this country (at the R.A.E., Farnborough) in the utilisation of phenolic resins moulded by vacuum and 'no pressure' techniques, like that described for the making of the hull of a boat. Silicone, epoxy and polyester resins moulded under low pressure, or 'no pressure' are also in use, though for the most part only on an experimental basis. The development of the reinforced plastics means that large structures can now be moulded without the use of high pressures and without big presses.

There can be no question of the important future that lies before reinforced plastics, nor of the challenge they present to British industry. Not only must designers think anew in handling these new materials, but their successful development and utilisation must depend to a very large extent on the active collaboration of all involved in their production. The producers of the basic materials, both plastics and reinforcers, and the manufacturers of the machinery for moulding and laminating must all play their part and combine not only their resources, but also their imaginations, if the best results are to be achieved and the full potentialities of the new material explored and made available for industry.

FREEZE-DRYING OF BACTERIA AND FUNGI

The resting stage—the seed—of the flowering plants is such a perfect affair that the bacteriologist and the mycologist have long envied the ease with which the botanist and the plant breeder can preserve their material. For what could be simpler than tucking away a sample of seed in a dry cupboard, knowing that when it is sown a year, ten years and sometimes even a hundred years later it will produce a perfect plant.* Simpler though the bacteria and fungi are structurally, they are by no means so easily preserved. In the case of bacteria, however, this paradoxical situation has been ended with the development of the technique of freeze-drying, by which it is possible to produce dried preparations that remain viable for many years. This is the method whereby water can be removed from a variety of materials, ranging from blood plasma and penicillin solutions to culture media containing living bacteria, by freezing followed by evaporation under vacuum, when the ice into which the water has been converted sublimes off. The same technique has also been tried in connexion with fungi as was mentioned in last month's article by H. A. Dade of the Commonwealth Mycological Institute.

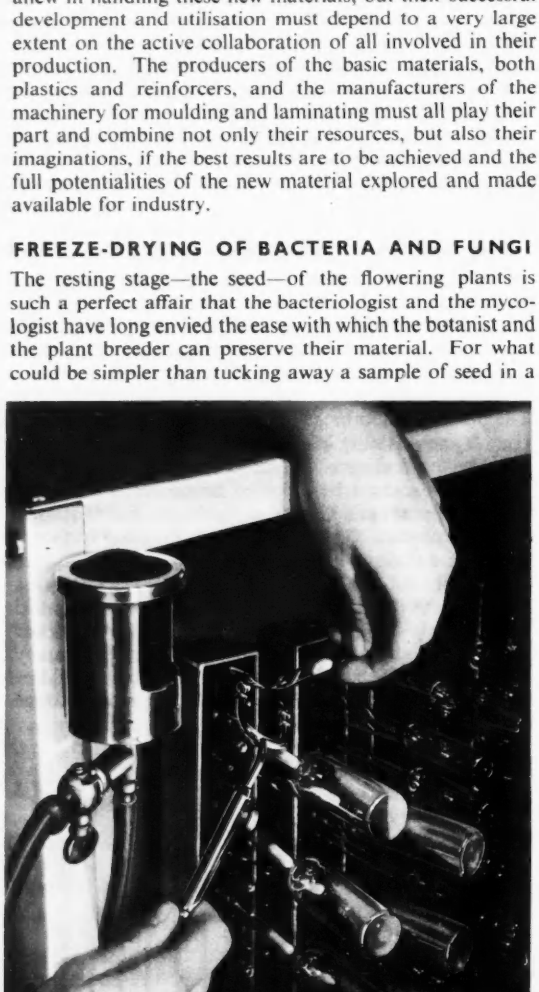

FIG. 4. Sealing ampoules containing freeze-dried cultures of bacteria.

Standard commercial equipment now exists which can take a batch of ampoules, each containing a sample of a bacterial culture, and freeze-dry their contents rapidly. The ampoules are sealed off under vacuum. The dried bacterial preparations so obtained can be kept at room temperature for a very long time without harm. At the National Type Culture Collection at Colindale these ampoules, appropriately labelled, are in fact kept in the compartments of a filing cabinet, and a preparation of any strain of bacteria can be removed when required and dispatched to any scientist anywhere in the world.

The vacuum remaining in the ampoule is tested by means of a small accessory. This is a high-frequency generator, which is held in the hand near the ampoule and switched on; the glow produced in the ampoule indicates the degree of vacuum. Such a test is applied to every ampoule before it is sent to a customer.

The preparation of viruses is on the same lines. The commercial freeze-drying apparatus is exported extensively to Africa for use by veterinary surgeons, which seems to suggest that it is successful for one vaccine at least—that for treating rinderpest. It is not going too far to say that the freeze-drying technique is one that without any great noise of publicity has made a revolutionary contribution to practical biology and medicine.

REFERENCE

"Freezing and Drying", Institute of Biology, 1951; this report of a symposium organised by the Institute covers industrial applications of freeze-drying and design of equipment; and the preservation of bacteria, viruses and mammalian tissues by freeze-drying.

DIESEL: WHAT'S IN A NAME?

The choice of popular labels for engines and other kinds of machines is frequently capricious. This is not altogether surprising for a number of considerations enter into the final choice; the primary purpose behind all such labelling is the aim to give everything a name which shall be unmistakable and easily pronounced. Other reasons can enter into the matter, while there are plenty of cases where the acceptance of a particular label owes something to the devices of publicity and propaganda.

* The record is held by seeds of the Indian lotus (*Nelumbo nucifera*); perfectly healthy seedlings have been produced from seeds that are at least 800 years old.

A case in point is the name 'diesel', which tends to be applied to all compression-ignition engines. The result is a measure of injustice to the other engineers whose contributions in this field are liable to be overlooked because lip service is continually being paid to the memory of Dr. Diesel.

Dr. Rudolf Diesel (1858–1913) studied engineering at a technical school at Augsburg and the technical high school at Munich, and became the Paris agent of the firm manufacturing refrigerators which Prof. Carl Linde started. Then, in the eighties of last century, Diesel went back to Augsburg and gained the support of two companies, the firm of Krupp and that of M.A.N. (Maschinen Augsburg-Nuremburg), in his search for an engine that would be more efficient than the existing gas engines. These two firms appear to have supported him during his period of experimentation. In 1892 he took out a patent in Britain for an engine designed in the first place to consume powdered coal. It blew up at the first trial in August 1893. He worked hard during the next few years developing the ideas put forward in the patent of 1892 almost out of all recognition so that the second engine he designed had comparatively little in common with the 1893 engine. He described his modifications of the original design to a meeting of the German Engineering Union in 1897, a fact recently brought out by Mr. H. Cowper, technical director of the British Internal Combustion Engine Manufacturers' Association, who has done considerable research into the origins of the diesel engine. That year, 1897, was the one in which the first real diesel engine was produced. It has been said that Dr. Diesel was no more the sole 'inventor' of the compression-ignition engine than King Charles was a breeder of a new variety of spaniel. What Diesel did do was to contribute notably to the achievement of high compression with its consequent high efficiency. At the same time an essential point of his system was that the combustion should take place at constant pressure (no explosion), and to some extent this does still happen in low-speed oil engines, but not at all in the engines used for automobiles. These are the surviving engine characteristics which Diesel introduced. But he was neither first with patents for a compression-ignition engine, nor the first to make one work.

Yet his name has stuck. Today every internal-combustion piston engine, other than gas or petrol engines, is called a 'diesel' engine by everyone, from garage mechanic to professor of engineering. This is naturally gratifying to Germany. Diesel's patent in that country was published early in 1893 and he followed it some time later with a book: *Theory and Construction of a Rational Heat Motor*. To celebrate this, on the 60th anniversary of the event, a memorial plate was recently put up in Augsburg, where in the M.A.N. museum there exists what is claimed as the diesel test motor of 1893–5. This motor is certainly not the one that blew up (unless it has been reconstructed), and is probably an early version of the one that was successful in 1897.

Long before this there had been compression-ignition engines in England. The pioneer was W. D. Priestman of Hull; his firm produced its first paraffin engine in 1887, based on a patent of 1885. The basis of the so-called 'heavy oil' or 'oil' engine, the engine that consumed a hydrocarbon of higher density and flash-point than petrol, was there stated, namely, the compression of air alone first and the injection of the hydrocarbon fuel afterwards (to be distinguished from the petrol-engine system in which a mixture of petrol vapour and air is admitted into the cylinder).

Priestman, however, still relied on a spark to fire the mixture. At about the same time a young Yorkshireman, Akroyd Stuart, was experimenting. British Patent 7146 of 1890, granted to Stuart, embodied most of the principles of the compression-ignition engine as used today. There was the primary compression of the air, the mechanical injection of vaporised hydrocarbon at the end of the compression stroke, and ignition of the mixture by means of the compressed—and therefore heated—air. The engine was produced in 1892 and became known as the Hornsby-Akroyd engine, and this was the first commercially successful oil engine. (The descendant of the firm that made it is today Ruston and Hornsby Ltd.)

In the Hornsby-Akroyd engine the fuel was vaporised in the end of the cylinder by heat applied by exhaust gases, though for starting the heat came from a lamp. He did not at the time achieve combustion alone. Dr. Diesel did, in 1897. In his later engines he made enough compression of the air to raise the temperature to the firing point of the fuel.

Diesel was a very persevering man completely obsessed with the idea of improving engine efficiency by widening the range of temperatures used. He based his work on the efficiency of heat utilisation which could be obtained in a Carnot cycle. This cycle was a theoretical conception of the action of an engine in which heat was turned into work in four stages, two at constant temperature and two under conditions that allowed no heat to pass in or out ('adiabatic' compression and expansion). In this ideal conception the efficiency would be given by $T_1 - T_2/T_1$, where T_1 would be the absolute temperature of the hot part of the cycle and T_2 that at which the heat was rejected. In steam engines of that time, T_1 was limited by boiler practice to about 200 C. (473° absolute). The temperature of the flame obtained by burning oil at the end of a compression stroke might be anything up to 1500° absolute. A little arithmetic, making reasonable assumptions for T_2, showed him the vast increase in efficiency possible.

In this work Diesel had the support of Krupp and M.A.N. when Germany was an energetic newcomer into the industrial world. He had the German love of theory—his first engine was to be a 'rational' one and exploited to the greatest extent the efficiency of Carnot's cycle. All these facts doubtless contributed to the perpetuation of his name, which, it seems, has come to stay. He was so successful with his publicity that the British Admiralty invited him to come over here for discussions, less than a year before the outbreak of the first World War. (On the channel crossing Dr. Diesel fell overboard and was drowned.) So it is as well in the interests of historical truth to put on record that the basic principles of the compression-ignition engine were laid down, and the engines made, in Britain.

IDEAS AND ASSUMPTIONS ABOUT THE ORIGIN OF LIFE

N. W. PIRIE
F.R.S.
Head of Biochemistry Dept., Rothamsted Experimental Station, Harpenden

We are so accustomed to discussing the origin of life and its essential nature that we tend to assume that these are old problems. But this is by no means so. From classical times down to the 16th century complex organisms were thought to arise from inanimate or no longer animate matter. For good results close attention to detail might be necessary, as the well-known prescriptions of Virgil and van Helmont for making bees and mice show, but no sharp distinction was seen between the living and non-living state.

This easy attitude continued into the 17th century both among scientists and the public at large, but times were changing and experiment began to oust confident assertion from its old place of honour. Redi studied the metamorphosis of insects and showed that at least one widely accepted form of spontaneous generation—the appearance of fly maggots on putrid meat—was caused by adult flies laying their eggs there. Homer knew this but Redi got it generally accepted and was able, at one and the same time, to open the attack on spontaneous generation and to invent the meat safe.

Experiments like Redi's forced the believers in spontaneous generation to change their ground and concentrate on putrefaction which they held could start in any material that retained some 'vital force'.

The idea of a vital force had much in common with Aristotle's concept of form; it has had a long life for it seems still to be believed in by some. As a contribution to the controversy about putrefaction, it had the defect that it made any experimental conclusion almost impossible. Processes which those who disbelieved in spontaneous generation looked on as methods for removing seeds, spores or contaminants were assumed to destroy the vital forces or substances in the medium. This was the central point of conflict between Needham and Spallanzani. Pasteur, writing a century later, saw this clearly and pointed out that, although in general scientific opinion Spallanzani had shown Needham to be wrong, no logical conclusion could in fact be drawn. In logic no conclusion was possible, but fortunately one developed from business enterprise. Nicholas Appert, at the beginning of the 19th century, published his method of preserving fruits, vegetables and meat by heating in a suitable vessel which was then shut, in the manner familiar to housewives, while still hot. The process was deservedly popular and people who were finding the products palatable and nutritious found it hard to believe that vital principles had been lost or that, if they had, they were of such fundamental importance as the Vitalists maintained. It may be argued that the discovery, many years later, that some of the vitamins are destroyed when food is preserved in this way, shows that people were wrong in drawing this conclusion, but the conclusion had its uses.

This phase of the discussion was effectively closed by the research, and even more by the combativeness, of Pasteur. His experiments did not actually refute the idea that sterilisation destroyed vital principles essential for spontaneous generation to take place but they made this seem less attractive than the alternative idea that micro-organisms are omnipresent, develop when given a chance, but can be removed. Pasteur introduced a clear idea of what was meant by a sterile culture medium and thus defined the general character of the controversy in its modern form. It was only after they had accepted Pasteur's conclusions that scientists became generally aware that the 'Origin of Life' was a fundamental and difficult problem.

Pasteur recognised that the main novelty of this aspect of his work was that he distinguished between germs in the air and other types of unstable agents that had been postulated. Furthermore, he made it unnecessary to assume the existence of any such agents. He was, however, careful and objective and, while riddling by experiment, argument and sometimes scorn all the various claims for the reality of spontaneous generation, he still admitted it as a possibility. In 1878 he wrote:

"La génération spontanée, je la cherche sans la découvrir depuis vingt ans. Non, je ne la juge pas impossible."

While species were thought of as fixed there was no satisfactory alternative to Special Creation. The idea of *an* origin of life had no meaning because it would only have explained one species and separate origins would have been needed for the others. But there were many pre-Darwinian believers in evolution. Darwin proposed a mechanism by which, without a pre-ordained plan or divine intervention, evolution could follow a steady course in building up structure and capacity in organisms. Darwin's forerunners thought that it had happened even if they did not know how, and as soon as they thought of evolution happening their minds were led automatically back to an origin of life. His grandfather, Erasmus, summed up the matter in verse:

> Without parents by spontaneous birth
> Rise the first specks of animated earth.

The stage was therefore set for a more co-ordinated discussion of the problem; people believed that life could evolve in non-living materials but they also believed that it very seldom did so.

From 1860 on there was intense discussion not only of the facts as then known but also of the implications. The level of awareness of what the argument was about, shown in the writings of Pasteur, Huxley, Tyndall, Errera, Allen and Schäfer, has not been bettered, nor even equalled, since. There is now a spate of books about the nature and origin of life and it would be well if the authors of those not intended simply as popular surveys would refer more adequately to the older authorities. This is usual in other fields of knowledge and it would help the reader to discover

what exactly the author claims as new in his presentation. It is unusual for physicists to write as if they had just discovered Boyle's Law for themselves, but, when they write on the origin of life, that is often essentially their manner.

In discussing the present position some subdivision is convenient but the items do not fall into any logical order; they are intimately intertwined. An attempt will, however, be made under the headings: Where did it happen? When did it happen? To what materials did it happen? And, most important of all: What exactly is it that is claimed to have happened?

WHERE DID IT HAPPEN?

The ancients accepted the possibility of spontaneous generation in lakeside mud and in their own back yards. As this view became untenable a bold attempt was made to avoid the whole problem by having the original forms of life arrive from some other planet. This 'cosmozoic' idea appears to have originated in 1821 with Sales-Guyon de Montlivault, and it has had a surprising vitality. It was taken up enthusiastically by Liebig, Richter and Kelvin and, even in this century, by Arrhenius and was the cause of much discussion and some experiment. The behaviour of spores and seeds under conditions of extreme cold and dryness was studied to see whether they were likely to survive in interstellar space for the time thought necessary if the pressure of light was moving them from system to system. Had scientists been aware then of the intensity of ultraviolet- and X-radiation in space, the studies would no doubt have been extended to include those agents.

The basic objection to the idea is that it does not explain anything. There is no biopoeic* factor or agency that it is easier to postulate on any other astronomical body than on this; partly perhaps because there is no need to postulate any special biopoeic agency at all. Schäfer wrote acidly that the idea "merely serves to banish the investigation of the question to some conveniently inaccessible corner of the universe". This is now generally recognised; if we are satisfied that the thing happened anywhere we might as well start with the assumption that it happened here.

The possibility of life on other worlds is, however, interesting, even if not strictly relevant. In considering it may we dismiss folklore, the meditations of Kepler on the order of precedence of man on Earth and on the other worlds, the fascinating wrangle between Whewell and Sir David Brewster which hinged essentially on the advantages that God might expect from having one or several types of Man to look after, and *The Moon Story* of R. A. Locke. The last was published in 1835 and describes in detail what may be best referred to as goings-on on the Moon said to have been observed through a gigantic telescope set up at Feldhausen in South Africa by Sir John Herschel. This work, along with E. A. Poe's *The Adventure of Hans Pfaall* and Jules Verne's *From the Earth to the Moon*, was the beginning of interplanetary fiction.

The surface features of Mars are still on the very edge of what is observable but at the opposition in 1909 Tikhov saw seasonal variation in colour and concluded that vegetation was green in spring and brown in autumn on Mars as on the Earth. He has shown that plants growing under the stresses of high altitude and low temperature at Alma Ata have colours very similar to those seen on Mars. For these and other reasons it seems logical to accept seasonal growth, and therefore life, on Mars. And if on Mars, no doubt on other satellites too.

The question "Where?" may therefore be answered, "Here or anywhere else provided an environment of suitable constitution is maintained under suitable conditions for a suitable time." The meanings to be given to the three *suitables* are themes for future research.

WHEN DID IT HAPPEN?

Before considering this we must look forward briefly to the last question which deals with the necessary qualities of a living system. Can we, for example, exclude the possibility that life could exist in an incandescent gas? Most people would now say "Yes"; but last century this was not so. Many tried to get round the difficulties defined by Pasteur by suggesting that life had always been about and that it had evolved into the present forms as our environment cooled. The idea satisfied some and appears in so many places that it is invidious to pick a particular originator, but Preyer and Pflüger developed it in more detail than the others. The latter thought of organisms made up of heat-stable cyanogen derivatives while others invoked compounds of silicon. This phase has now passed. If anyone found a high-temperature system behaving in an even more lifelike manner than flames do, the phenomenon would be called an interesting analogy with life rather than the beginning of Asbestobiology.

There is an even older variant on this idea which attributes life to everything in the universe. This was implicit in Leibnitz's monads, and it reappears from time to time. Samuel Butler remarked, "Every atom in the universe is living." It is not easy to see what he meant. The dictum obliterates all meaning in the word 'living' without enhancing in any way our understanding of atoms. Butler was writing for effect; there is less excuse for some recent, ostensibly serious, writers who get near the same idea and stress the internal complexity of atoms. No doubt the atom has an elaborate organisation, but the analogy that every intelligent adolescent thinks of between the atom and a solar system is as close and just as useful.

If, therefore, we arbitrarily restrict the domain of Biology to cool solid and liquid systems, the time at which life could have originated clearly depends on the time when the earth had a cool crust. Generally the time is narrowed still further to the time at which liquid water could lie on that crust, but the value assigned by the cosmologists to this date has varied greatly during the period in which biologists have wished to know it. The suggestions made in the 19th century, while they seemed shockingly early to believers in Genesis, were much too late to satisfy those who considered the thickness of the sedimentary rocks or

* Biopoesis (the cognate adjective is biopoeic) seems a more suitable word than Huxley's *abiogenesis* for the making of life *de novo*. Words ending in *genesis* carry a sense of generation as in animals; the making of like by like. *Poesis* is more suitable here because it is making in the sense of creating from something quite different. It is the root from which we get many physiological terms and also the word poet. The poet is still called a maker in Scotland. This makes it particularly apt, for the original biopoesis was quite a flight of fancy.

the rate of evolutionary change. These values were based on the idea that the Earth was initially a hot wisp of solar material that had cooled off and they depended on calculations of the rate of cooling. The discovery of radioactivity, and so of an internal source of heat in the Earth, removed their validity.

Recent estimates of the date also run into difficulties. Some think the Earth started as a hot body and some that it was built up by the accretion of various forms of cold interstellar detritus. Some think it has a ferro-nickel core, others a core of compressed hydrogen which takes on quasi-metallic properties because of high pressure; still others think that it is made predominantly of magnesium silicate all through. Even this group is divided, some think there is discontinuity in chemical constitution and others that the apparent discontinuity is a phase change due again to high pressure. No doubt these difficulties will be resolved and more possibilities may be suggested; in the meantime we must turn to other lines of evidence. We should remember, as we turn away, that it is only because there are so many people working in these fields that the inconsistencies have shown up. Each astronomical or physical expert has been dogmatic about the conclusions reached by his method. We should be wary of all interpretations until they have been subject to criticism for several years.

3,000,000,000 years is an approximate figure for the time that has elapsed since the formation of the older rocks of the Earth's crust and it is given by two independent methods of dating. One depends on the assumption that certain minerals initially contained no lead but gained lead from the radioactive decay of uranium. Knowing the rate of decay and the present concentrations of uranium and lead their age can therefore be calculated. The other depends on the assumption that the nebulae have always been receding as they do now so that a time can be calculated at which the Universe started with all its matter in a small space. The fossil record first becomes abundant in the Cambrian, about 500,000,000 years ago, but there are various structures in Pre-Cambrian and even Archean rocks that some authorities take for traces left by simple organisms such as calcareous algae. Somewhere, therefore, between these two dates lies the point of origin of the types of phenomena that we are accustomed to accept as living. Recently another interesting measurement has been made that tends to confirm this date. The sulphur in very old deposits of sulphide, sulphate and free sulphur has the same isotope ratio as meteoric sulphur, but in deposits laid down less than 800,000,000 years ago this is only true of sulphate. In sulphides and free sulphur the proportion of S^{32} tends to be higher. The simplest explanation of this is that these have been made by a biological process that shows some selectivity for isotopes and that this only became significant 800,000,000 years ago.

Morphologists are apt to look on the beginning of the fossil record as lying somewhere near the time of origin. Biochemists, on the other hand, have a different scale of complexity. Even the simplest organisms have as complete a range of biochemical accomplishments as those that are more complex. So far the study of evolution has been the study of the evolution of structure because that is what leaves a fossil record. We know a little about the biochemical specialisation that has gone on during this period of morphological evolution but nothing about the evolution of new biochemical capacities. But it is clear that there was a phase in the Earth's history in which biochemical evolution was an active process. Even if all the systems of metabolism that we now know did not then arise it is probable that many of them did, and that the first organisms to leave fossils used much the same chemical machinery as is used now. The time occupied by this phase is guesswork, but there is no basis for assuming that it was shorter than the time required by the morphological phase. Organisms of a sort have probably existed for 1,000,000,000 years and may have existed for twice that time. It is important to remember, however, that the change that came over Biology in the Cambrian was more important qualitatively than quantitatively. Now there is about 20 times as much matter in the form of bacteria as there is in the form of animals; the change in the last 500,000,000 years is only that the animals have gone up from 0% to 5% of the non-vegetable mass. It is more difficult to make any similar statements about the plants because the record is less clear.

The next obvious question is, "Did life originate once only and did all other species evolve from the original one or have there been constant new originations?" There is little basis for a firm opinion on this matter. The main evidence for a single origin is the tendency of present-day organisms to use a restricted number of substances in their metabolism and structure and especially the preponderance of one stereoisomeric* series of amino-acids in protein building. This uniformity has only been adequately demonstrated in organisms that get an obvious advantage from it because they form a food chain. Few present-day species bring new inorganic matter into circulation; most of this work is done by the green plants for which a common origin is generally conceded. If they introduce molecules with a particular stereoisomeric arrangement into the system there will be selective pressure on organisms that depend on plants either directly or indirectly, favouring those which use these stereoisomers. Only if the plants produced both types of molecule with equal readiness could the uniformity among animals and bacteria have significance.

There seems to be no reason to doubt that if life originated once it may have done so many times and may still be doing so unrecognised. The old attempts to demonstrate this failed—they were indeed unnecessary, for substantially similar conditions to those arranged in the laboratory were being arranged by the million in the food canning and bottling industry. Three factors militate against our recognising spontaneous generation if it takes place now; we do not know what types of medium it is most likely to occur in; we do not know what manifestations to look for; in any of the extensive natural

* Various chemical configurations differ from each other in the same way that the right and left hand do, so that there are two forms identical in all respects except that one is the mirror image of the other. These are stereoisomers, and in the same way that normal, or right-handed, bolts, wood screws and corkscrews, form a family with similarity underlying their functional difference so also amino-acids are a series of substances differing in detail but having a common asymmetry.

environments any newcomer would be likely to get used as a metabolite by an already established type before we noticed the arrival.

The conclusion reached in these two sections is therefore that no other place and time seems more suitable for the appearance of life than here and now.

TO WHAT MATERIALS DID IT HAPPEN?

Before we can consider how it happened we must decide what materials were available for the original biopoesis and on this question disagreement is rampant. Disagreement among the cosmologists about the origin of the Earth leads to a disagreement about the probable composition of its surface and of its original atmosphere. This probably contained little or no O_2. Opinion about when O_2 appeared depends on the mechanism proposed for its formation. Herbert Spencer, struck by the fact that the estimated weight of coal and oil in the world was approximately equivalent to the weight of O_2, suggested that it appeared in the Carboniferous and was a product of plant metabolism. With minor modification this has been accepted by many though there are points of difficulty. In general the iron in igneous rocks is in the ferrous state whereas there are immense deposits of Cambrian or even Pre-Cambrian sedimentary iron ores in the ferric state. It is hard to see how this could have happened unless O_2 was already present in the atmosphere before the coal measures were laid down. The theory demands the simultaneous appearance of O_2 and substantially unoxidised carbon. Spencer assumed that this was Carboniferous coal but it might have been Pre-Carboniferous oil. The idea that O_2 is a product of photosynthesis presupposes that CO_2 is an original atmospheric component. Poole argues convincingly in favour of it, and Urey equally convincingly that CO_2 was derived by the oxidation of methane after O_2 had been produced. They agree that most of the original O_2 was not produced by photosynthesis but by the decomposition of water vapour exposed to ultraviolet irradiation in the upper atmosphere, followed by the loss of the H_2 into space.

Spencer's numerical relationship remains even although we may accept the unanimity of the experts and agree that it is fortuitous. It has an interesting consequence for the future of life even if it has no bearing on its origin. We are often told that, at present rates of consumption, all the coal, oil, lignite, etc. will be used up within a number of years that varies according to the political and social prejudices of the writer. It is not easy to see what the writers mean for all the O_2 would then be consumed and replaced by CO_2 and water. Long before this could happen the fires would have gone out unless some new source of O_2 were provided. Even the burning of a significant part of the Earth's carbon would raise the CO_2 content of the atmosphere and so of the oceans. The biological effects would be striking. Expressed as grammes per sq. cm. of the Earth's surface, carbon is at present distributed: 0·4 in the atmosphere, 20 in the sea, 1000 to 3000 as coal, oil, etc. and 700 as carbonates. If much of that 1000 to 3000 grammes is added to the atmospheric and oceanic quota, the growth of plants will be stimulated, but it is unlikely that this will suffice to keep the atmospheric concentration constant. We will therefore start panting as if we had just finished a race and the new equilibrium reached between the atmosphere and the sea will make the latter more acid. Before all that happens we are likely to decide to use new energy sources.

Poole and Urey also disagree about N_2. The former has it as a primary component and the latter agrees with Vernadsky and Oparin in making it secondary, deriving it from the oxidation of NH_3. There is fair unanimity that NH_3 was present; for our present purpose it is not perhaps very important to know whether there was also N_2 in quantity. Its compounds play a fundamental role in life now and may well be important in biopoesis, but the gas itself is too inert at ordinary temperatures for it to be likely that it was important.

The rest of the atmosphere is thought to have been made up of volatile reduced substances such as HCl, H_2S, boron and phosphorus compounds, and so on. How these would partition between the atmosphere and the ocean depends on a series of assumptions. Two things are clear. There is very little knowledge about the state of the surface of the primitive earth and the more probable guesses suggest that it was highly unlike any environment in which we now grow, or even try to grow, micro-organisms. As if this were not enough to inhibit the more detailed framing of speculations another difficulty has been suggested by Haldane. Whether we interpret the observed reddening of the light of distant nebulae as evidence that the universe is expanding or that atomic constants change with time, he argues that the properties of the chemical elements and the energy derivable from chemical reactions are not the same now as they were 500,000,000, or 1,000,000,000 years ago. Related conclusions had already been suggested by Milne and Whitrow, but unfortunately they have not been either contradicted or taken into account by others discussing biopoesis. Haldane and Hotspur seem essentially to agree that life is "time's fool".

The tentative picture we form of the surface of the probiotic Earth is only definite enough to make it certain that it was unlike the present surface. A few necessary conclusions follow. If the ultraviolet radiation from the sun was approximately as strong then as it is now, Haldane points out that it would have brought about an extensive range of syntheses at the Earth's surface in the period before there was much O_2. (Today almost all the ultraviolet light is absorbed by ozone in the upper atmosphere so that now these syntheses are unimportant.) Without either O_2 or micro-organisms the products of synthesis would accumulate so that a rich organic soup would be ready for the earliest organisms to grow on. Haldane's idea has been accepted with minor modifications by Oparin and almost all subsequent writers and it puts a little meat on the skeleton provided by Pasteur, Huxley, Tyndall, Allen and Schäfer. But we are far from being able to make a detailed likeness. The stage is set for biopoesis and the environment is beginning to look a little more like that of the present day, but we could arbitrarily choose almost any time for the first biopoesis in a span of possibly 1,000,000,000 years before the Pre-Cambrian. The most probable time depends on the qualities we decide to insist on before we call a system living.

WHAT IS CLAIMED TO HAVE HAPPENED?

During the last three or four centuries, the period in which Life has been widely accepted as a metaphysical entity, innumerable people have tried to frame a definition of it. A few moments is sufficient to think of a flaw in the definitions both ways. That is to say, to think of a system that we all agree to call alive and which would not be included by the definition and to think of a chemical or mechanical arrangement that would do all that the definition requires. Descartes had already seen this when he argued that animals could not be logically distinguished from mechanical automatons. His concept of the beast-machine aroused repugnance; his contemporaries felt that there was something different about an animal, and we, though we are now aware of vastly greater possibilities in machines than Descartes was, share the feeling. A feeling is, however, a very different thing from a rigid definition or even an adequate description. We can dismiss quickly most of the criteria; these come in because people think about the large, and probably recent, developments of life and attach importance to irritability, movement and so on. Historically movement is important as is shown by the old contrast between the quick and the dead and the still current usage of viviparous to mean producing active young. But many bacteria and most plants show neither. And so with the other criteria; each is well adapted to a certain type of organism and ill adapted to others. Also each is shown by a man-made system. Life is not a thing or philosophical entity: it is an attitude of mind towards what is being observed. When we ask when did life originate, we should not expect ever to get a clear answer because only opinion is involved. Even after there has been a vast increase in knowledge the answer will only take the form, "At a certain date there were systems that 1% of observers would wish to call alive, at a later date 10% and so on . . ."

There are two sorts of relevant property: what the system is made of and what it does. The first is often settled by edict. "Living systems contain proteins." So far as is known this is an accurate statement now but the dogma springs from Purkinje's concept of protoplasm and that is itself apparently derived from a liturgical reference to Adam as 'protoplastus'. Most writers now write protein instead of the rather old-fashioned protoplasm. This seems to limit the problem unreasonably. It is undeniable that proteins offer effective machinery for carrying on the affairs, enzymic and otherwise, of an organism, but this may only mean that they are the most effective —not the only—way of working. If we found a system doing things that satisfied our requirements for life but lacking protein, would we deny it the title? It is worth while remembering that, although the statement is often made that *all* living organisms contain protein little effort is put into showing even that every phylum does, let alone every species. But they probably do—now. Proteins have an immense diversity of properties although all are made by arranging approximately the same group of 25 amino-acids in different ways. It may be that their outstanding merit, as vehicles for vital activity, lies in the housekeeping economy that this makes possible. They have the same merit as an alphabetical language which produces an almost infinite variety by ringing the changes on twenty-six letters.

If this interpretation should be correct it would be compatible with a gradual rather than an initial assumption of importance by proteins. In early systems, which may be called eobionts,* functions may have been performed by other materials, inefficiently no doubt but well enough to get things started. Thus hydrated silica, alumina, cyanides, phosphates and carbonates absorb molecules and hold them in a spatial array in a manner comparable to that in which they are held, or assumed to be held, by proteins. Goldschmidt points out that calcium phosphate and carbonate still play a role that amounts to symbiosis in many organisms, and he has stressed the catalytic activities that might result from the absorption of components of the probiotic soup on the edges and corners of mineral crystals. Bernal proposes a similar role for clay. We know too little about the physical chemistry of adsorbed molecules to be able to see clearly which idea is the more advantageous.

Further speculation is unprofitable, but it is worth while emphasising that the field for possible speculation should not be narrowed unnecessarily. Because there are small particles in cells that seem to be able to grow and multiply at the expense of the cell contents, some people have suggested that eobionts were also small. There is no logical necessity in this. It may be easier to think of means by which the activities of an eobiont could promote more eobiont if those activities are spread over an acre and through many intermediates. The bugbear of discussions on this theme is the premature attempt to draw up a detailed scheme in terms of present-day ignorance. In this article ignorance and uncertainty, not only of the facts but of whole domains in which significant observation could be made, have been emphasised. The result is vague and sketchy. Nevertheless it will probably seem a cocksure over-estimate of the relevance of present knowledge to anyone who reads it in thirty years' time.

* Eobiont = 'dawn organism'. Made by using the prefix *eo-*, as in the geological epoch Eocene.

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CHEMICAL ENGINEERING: THE FOURTH TECHNOLOGY

E. A. RUDGE
Ph.D., A.M.I.Chem.E.

The first chemical engineering text-book was published in Britain as long ago as 1901. In spite of this the importance of this fourth primary technology has not been fully recognised, with the result that there continues to be a lack of trained chemical engineers. Another result is that the career prospects in this profession are extremely good. The author of this article is Principal of West Ham College o Technology, and has been concerned with chemical engineering courses ever since 1919. He has served on the Board of Examiners and the Education Committee of the Institution of Chemical Engineers, and on the Board of Studies in Chemical Engineering of the University of London.

Chemical Engineering has been defined by Sir Harold Hartley, past-president of the Institution of Chemical Engineers, as the *fourth* primary technology, ranking along with Mechanical, Civil and Electrical Engineering, upon which industry is completely dependent. To a great extent these four are closely interwoven, but each holds a unique place in the development of this industrial age.

Civil Engineering is the oldest technology, reaching back to the early days of the Industrial Revolution, with its need for roads and bridges. Close upon its heels came Mechanical Engineering, which emerged during the development of steam-driven machinery at the beginning of the 19th century; this was followed some fifty years later by the dynamo and the rise of Electrical Engineering. Chemical Engineering is the youngest of the group and its recognition dates only from the turn of this century.

It was the first World War which initially emphasised industry's need for the new technology. Up to that time, the chemical industry had been largely a matter of 'hit-or-miss' empiricism; for although the 19th century was the period of rapid expansion in chemical theory, and witnessed the founding of teaching and research institutions, chemistry had made little impact upon industry; the breathless discoveries of science had not appreciably influenced the course of the old-established manufacturing methods. Even up to the year 1914, nearly every factory had its jealously guarded 'trade secret' which in the majority of cases turned out to be nothing more than an experimental variation of the process handed down through the generations. The 'Works Chemist' was a comparative rarity, and the graduate leaving college for industrial employment would invariably be called upon to pay a premium to the employer for the privilege of 'learning the process'.

THE LESSON OF THE FIRST WORLD WAR

Such was the general industrial background towards the end of the 19th century, but already a new Chemical Industry was coming into being. This developed along two parallel lines. One was the so-called 'heavy chemical industry', expanding from the great and growing demand for acids, alkalis, fertilisers and explosives. The new chemical science at first had little effect upon the traditional methods of these industries, but when the first World War created a sudden call upon their resources, the old rule-of-thumb technique showed its complete inadequacy to meet the emergency. Then, as never before, it became clear that a new kind of technician was essential, a chemist, skilled in the knowledge of the laboratory and also able to work with the methods of the engineer, so that he could translate the reactions of the test-tube into the terms of satisfactory output.

The second line of development began in the field of organic chemistry, rapidly expanding from the researches of an increasing army of British and foreign chemists. New industries appeared, in dyestuffs, high explosives, coal by-products, disinfectants, antiseptics and plastics; and for these industries there were no traditional methods. Here again, a new type of industrial chemist had to be trained.

But the graduate emerging from the college laboratory soon proved to be wholly inadequate for the complex and responsible needs of these growing technologies, and many makeshift devices were employed to meet the crisis. One of the most remarkable phenomena of the war years 1914–18 was the manner in which raw young graduates added their scientific knowledge to the skill and experience of workmen in our chemical industries, and in turn acquired a competent knowledge of process control.

Yet such methods of meeting an emergency were hazardous, and already men of vision were advocating a new kind of training. The name 'chemical engineer' was adopted, and in 1922 the youngest technology became recognised in the formation of the Institution of Chemical Engineers. Syllabuses of training and standards of examination were drawn up, and a few colleges made the bold experiment of planning definite courses of chemical engineering study.

It would be true to say that from the beginning until very recent times the development of chemical engineering has been fostered entirely by this institution. No less true is it that almost to the present day, schemes of training failed to settle down into a systematic study. This was largely due to the fact that there was much more empiricism than knowledge of the fundamentals involved. Take a simple case—that of distilling a liquid. By experience over many years, distillation had evolved by trial and error from the simplest apparatus; but the principles of heat transfer, fluid flow, fractionation and condensation were but vaguely understood. The science was so new that very little research had been accomplished, and all too little data available. Two methods of teaching, therefore,

grew up side by side. One method trained its students in the experimental use of semi-scale plant, bridging the gap between the laboratory test-tube and the factory plant by introducing new materials of construction and new methods of control. This system had much to be said for it, but it has gradually been superseded by the method of training in fundamental principles commonly adopted today. I believe it was the late Mr. J. W. Hinchley, the first Professor of Chemical Engineering at Imperial College of Science and Technology in London, who introduced the scientific aspect into chemical engineering training; he taught his students, for example, how heat passes from a gas-flame into a bowl of water, at what rate chalk will settle from a watery suspension, why one metal corrodes in a given set of conditions whereas another does not, and the hundred-and-one similar fundamental facts upon which all chemical industry is built.

The training of the chemical engineer today follows a definite pattern, which has been worked out from the experience of the past thirty years. Its aim is to make the student a tolerably good chemist, familiar with the behaviour of elements and compounds. He must be an excellent mathematician, for mathematics is one of the most important tools of his profession; he should be a sound physicist, for applied physics is in truth the very basis of chemical engineering; and in addition to these he must be an engineer, in the sense that he should know how heat and power are generated and used, how the common materials of construction are fabricated into his plant, and how to read a working drawing. Beyond all this, he should know something of civil engineering, how to develop a factory site, and to lay out the essential features of a works; he must be a little of a lawyer, able to apply factory legislation to his problems; but above all, he must be a practical business man, for it is of little use designing a plant to make a product if it cannot be sold at a profit.

DEGREE COURSES

Such a course of study as I have outlined here may appear a formidable if not an impossible task for any normal student, yet the fact remains that it is in active operation as a course for a university degree in chemical engineering, with as high a percentage of passes in its examinations as any other course. Students enter with the Advanced Schools Certificate in the essential subjects of Pure and Applied Mathematics, Physics and Chemistry, and thereupon follows a three-year full-time syllabus. For the London University degree, the examination is divided into two parts, and although there are sixteen examination subjects in all, they are spread over the full three years. In the final year the student proceeds to the study of the more specialised subjects of Fuel and Combustion, Materials of Construction, Heat Transmission, Power Generation and Unit Chemical Engineering Operations. This last item is without a doubt regarded as the most important subject, for it consists of a fundamental study of the underlying theories and practice of such processes as separation and mixing, evaporation and distillation, crushing and grinding, crystallisation, etc., treated from the point of view of the physical laws upon which they are based. In addition, the student makes a study of the industrial application of the familiar chemical operations such as oxidation and reduction, nitration, polymerisation, electrolysis, etc.

Up to this point, the young chemical engineer has had no contact with industry beyond an occasional works visit, and spells of employment during the college vacations, and as a newly fledged graduate he enters employment with an open mind, academically equipped to take his place in the world of commerce.

With the coming years there is no doubt at all that this new degree in chemical engineering will make a valuable contribution to the personnel of industry, despite the opposition which still exists among the small but influential section of employers who stubbornly hold to the old-fashioned idea that our modern complex industries can be run by mechanical engineers and pure chemists alone.

Before this degree course was designed, the only system of training in chemical engineering was the so-called 'top-dressing' course, by which men who had already gained a graduate standard in mechanical engineering or in chemistry followed a short and intensive study of specialised subjects. Originally this course was sponsored by the Institution of Chemical Engineers, which conducted the examinations for its Associate-Membership on its completion; but during the second World War, the scheme was energetically adopted by the Ministry of Education as a means for the rapid supply of chemical engineers for our war-time industries.

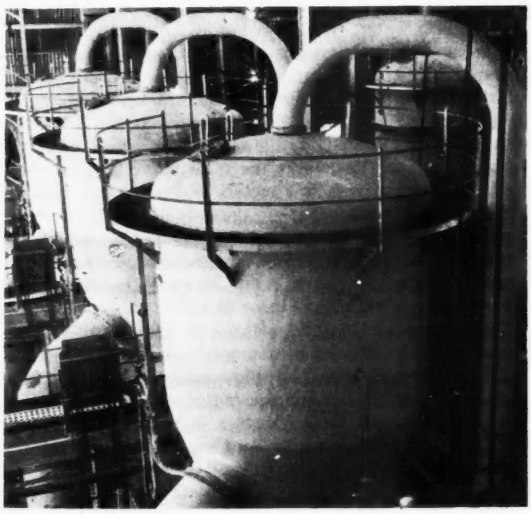
THE NATIONAL CERTIFICATE COURSE

Finally, as recently as 1952, the technology of chemical engineering came into line with its sister technologies with the provision of a National Certificate Course, awarded jointly by the Institution of Chemical Engineers and the Ministry of Education. It is a part-time evening course, held at present in a very few Technical Colleges, such as Battersea and West Ham. The students are employees in the chemical industries holding at least the Ordinary National Certificate in Engineering or in Chemistry, and the three years of study provide a sound fundamental training in the theory and practice of chemical engineering subjects.

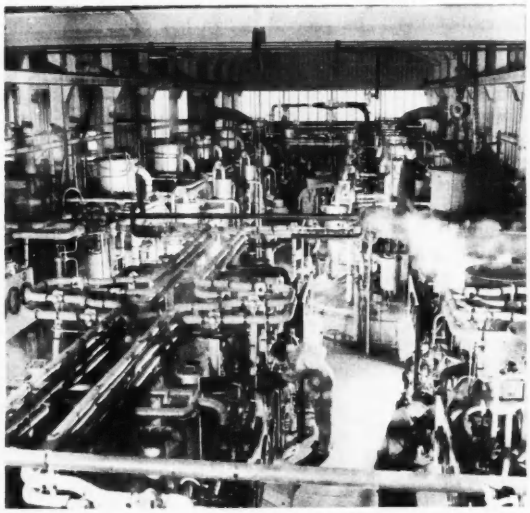
Yet with all these provisions, the supply of chemical engineers remains a miserable trickle, and the annual output of trained men is woefully inadequate for the growing needs of industry. It is no exaggeration to state that for every graduate completing his studies there are five attractive posts waiting to be filled. This shortage has been emphasised time and time again by competent authorities. The 'Percy Report' on Higher Technological Education summed up the situation in the words—"the greatest deficiency in British Industry is the shortage of scientists and technologists who can administer and organise. . . . Industry therefore requires a responsive and adaptable organisation of technological education." On this point it should be stressed that the shortage is not entirely due to any shortcomings in education, for today even the few available training centres in this country are far from full. The plain fact of the matter is that all too few pupils of Higher Certificate attainment are leaving the grammar schools to continue in full-time university study, and all

EXAMPLES OF THE CHEMICAL ENGINEER'S SKILL

One out of every ten of Britain's chemical engineers is employed in the oil industry. This picture shows the 'cat-cracker' at Stanlow Refinery, where chemical engineers are now engaged on the work of building the first British 'platforming' unit which will convert low-grade petrol into high-grade spirit by a new catalytic process that is markedly different from 'cat-cracking'. (*Shell photograph.*)



Fixing atmospheric nitrogen to provide ammonium sulphate for use as fertiliser is one of the chemical engineer's triumphs. Nine of these huge evaporators at the Sindri fertiliser factory in India concentrate and crystallise 1000 tons of this material per day. (*Courtesy, Power Gas Corporation.*)



The chemical engineers had many tricky problems to overcome to bring antibiotics such as penicillin and streptomycin into large-scale production by the deep-tank process. The tops of the vessels used in this process are visible in the background: in the foreground are the small seed tanks. (*Glaxo Laboratories photograph.*)

too small a proportion of these elect to follow the degree course in chemical engineering. This may be due to lack of information about this attractive and lucrative profession, or it may be due to economic reasons inducing young people to seek employment at an earlier age. It seems clear that the careers masters of the grammar schools are partly responsible, in failing to deflect their university pupils from the overcrowded professions of engineering and chemistry into the ever-increasingly important one of chemical engineering.

It is interesting to compare conditions in this country with those in the United States of America. It has been estimated that the *total annual output* of Chemical Engineers from all sources and methods of training in Britain is 200, produced by a small number of training institutions which may be enumerated on the fingers of both hands, and mainly from Imperial College of Science and Technology, University College and King's College, London; Cambridge University; Birmingham University; the Colleges of Technology at Manchester, Loughborough and West Ham; Battersea Polytechnic and Bradford Technical College; and the Royal Technical College, Glasgow. Now compare this with the American picture, where, "in 1949–50 the number of first degrees granted in Chemical Engineering was 4529". Without a doubt there is some truth in the view that "these large numbers have had an important bearing on the rapid progress of industry in the United States", to quote the Dunsheath Report on the Relations between Universities and Industry in the U.S.A.

As recently as April 1952, Sir Harold Hartley trenchantly described the present crisis as "chemical engineering at the cross-roads", pointing out that until we recover the initiative in chemical plant design and construction, we shall be forced to import the 'know-how' at high cost from abroad.

It has become trite and commonplace to assert that our economic survival is geared to our industrial efficiency and invention. It should also be recognised that efficiency and invention are largely dependent upon a greatly increased flow of recruits into chemical engineering practice and research, and our schools and colleges should for many years to come regard recruitment into the Fourth Technology as of the highest priority.

THE FIRST BREEDER REACTOR

The Experimental Breeder Reactor, which has established the possibility of breeding nuclear fuel, was put into operation early in 1952. Built at the Reactor Testing Station of the U.S. Atomic Energy Commission at Arco, Idaho, it may be ranked as the most important reactor since the original Chicago pile with which the practicability of the controlled chain reaction was demonstrated in December 1942. Its general design has now been made public by W. H. Zinn, director of the Argonne National Laboratory, and a schematic drawing of the design is published on the next page.

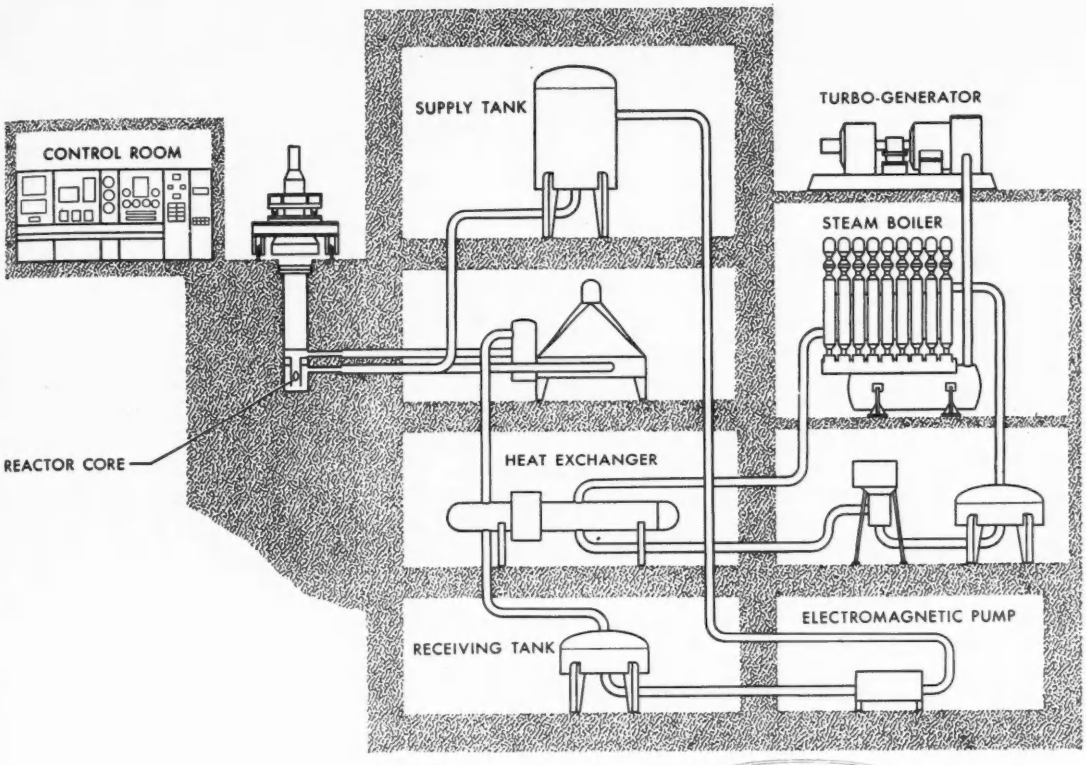
The Arco breeder was designed to explore the answers to several questions, but the key one was whether a nuclear reactor could be made to manufacture more fuel than it burns. Its assignment was to burn the fissionable U235 in natural uranium and, with the neutrons from U235 fissions, to convert the much more abundant U238 in the mixture to fissionable plutonium. The fission of U235 atoms releases an average of 2·55 neutrons per atom. One of these neutrons must be captured by another U235 atom to maintain the chain reaction; for breeding to succeed, more than one of the remaining 1·55 neutrons must be captured by U238 to make plutonium.

The experimental breeder is designed to cut neutron losses to a minimum and ensure that as many as possible find their way to U238 atoms. Its reacting core is tiny—about the size of a football. Because the materials used in a reactor to slow down neutrons all absorb some neutrons, this reactor has no moderator: it operates with fast neutrons. Around the core is a blanket of U238, which catches neutrons to form plutonium.

All of the reactor's power is generated as heat in this small core. The coolant that picks up the heat and carries it to the electricity-generating unit is a liquid metal—an alloy of sodium and potassium. This alloy does not appreciably absorb neutrons and has excellent characteristics as a heat transfer medium: for example, it is liquid at room temperature but has a high boiling point, 1500 degrees. It is, however, extremely active chemically: it burns vigorously when exposed to air and explodes on contact with water. It is also highly radioactive because of its exposure to neutrons. Hence it must be handled carefully. Emerging from the core at a temperature of 660 degrees, the coolant flows through a heat exchanger, where it gives up its heat to a second circuit, and is then pumped to an elevated storage tank, from which it begins its circuit again. To handle the radioactive liquid metal, special pumps, valves, flow meters and other instruments had to be designed. One of these is a unique 'electromagnetic pump' without moving parts. It operates much like an induction motor: electromagnetic forces move the liquid metal through a duct in the same way that they force the rotor of an induction motor to turn.

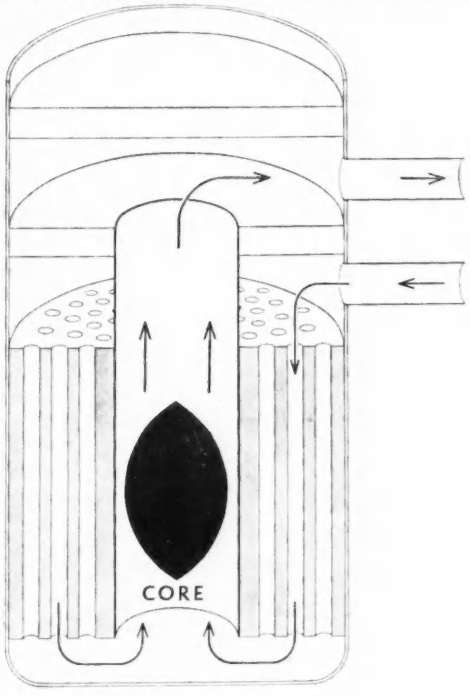
The section of the plant through which radioactive coolant flows is enclosed by a concrete shield. The second circuit of sodium-potassium alloy, which takes the heat from the first, does not become radioactive and is outside the shield. It transfers the heat to a steam boiler of special design. With sodium-potassium alloy and water together in the same apparatus, the boiler must be constructed so that they cannot come into contact with each other.

The reactor core has the highest flux of neutrons known —650 million million neutrons per square inch per second. This creates a severe problem because a high neutron flux breaks down the physical structure of all materials and equipment exposed to it, including the uranium itself.



(*Above*) Schematic diagram showing breeder reactor with associated energy-converting equipment. The wide grey walls represent concrete shielding, which encloses the core and radioactive primary cooling circuit. In the heat exchanger a secondary circuit takes heat (but not radioactivity). The space used for energy production is small compared with the space occupied by equipment for energy conversion.

(*Right*) The core and the blanket of ordinary uranium (which is composed mainly of U238). Neutrons from the chain-reacting core are absorbed by the U238 atoms of the blanket, synthesising plutonium. Liquid metal coolant flows through the blanket and past the core and emerges at 660 F.

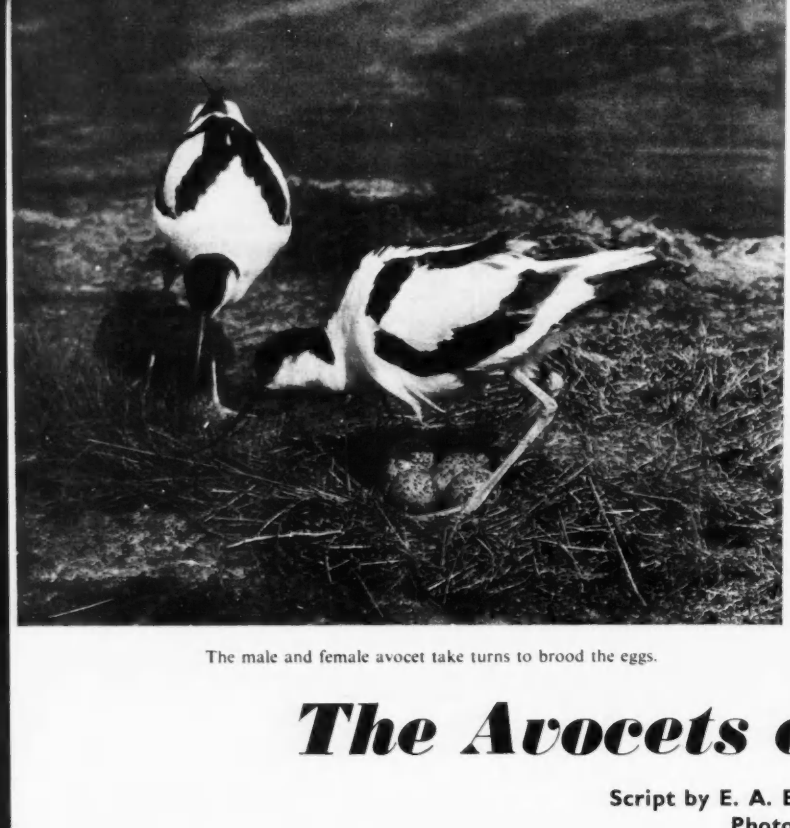


The AEC has not disclosed how heat can be transferred efficiently from the very small reactor core. The reactor yields four kilowatts of power for each cubic inch of the core, whereas a modern oil-fired naval boiler gives only six-tenths of a kilowatt per cubic inch.

The experimental breeder is producing enough power to supply its own electrical machinery.

A number of private industrial firms in the U.S.A. are now studying the possibilities of commercial atomic power. The Dow Chemical and Detroit Edison group recently indicated that it thinks breeding is a good bet to succeed. This group proposes to build a pilot power plant using a high-temperature breeder reactor. It has said that it is willing to undertake the project with its own funds and without a government-guaranteed price for plutonium made in its plant.

(*This article is published by arrangement with "Scientific American".*)



The male and female avocet take turns to brood the eggs.

Turn[illegible] eggs.

The Avocets of Havergat[illegible]

Script by E. A. ELLIS, of the Castle Museum, Norwich
Photographs by ERIC HOSKING

Three hundred years ago, Sir Thomas Browne tells us, "Auoseta calld shoohing-horne, a tall black and white bird with a bill semicircularly reclining" was familiar enough on the coastal marshes of Norfolk in summer. Early in the 19th century, by which time much coastal land in East Anglia had been embanked, drained and rendered familiar and accessible to villagers, we hear of avocets' eggs enriching puddings and pancakes of the poor at Salthouse, N. Norfolk, and of shore gunners making a bit 'on the side' by securing avocet plumes specially coveted by fly-fishermen. Egging and shooting exterminated the last few nesting colonies before the middle of the century; thereafter, even with the introduction of Wild Bird Protection Acts, visiting avocets stood little chance against gunners ever ready to obtain them for taxidermists and collectors. So, while these lovely birds continued to breed just across the North Sea, any tendency for them to settle again in their former haunts in this country was rudely and persistently discouraged.

Many an East Anglian ornithologist cherished a hope, but scarcely a conviction, that avocets might return. For one thing, suitable nesting sites became rare by the end of the 19th century, and for another, it became more and more difficult to imagine that any attempt at recolonisation could succeed in a country so filled with amateur bird viewers and bird photographers.

Then in 1938 interest was aroused when two pairs of avocets suddenly decided to nest in Ireland. In 1939 came the war, and the East Anglian coast soon afterwards became a kind of no-man's land. It is now known that single pairs of avocets nested, but lost their eggs, at Salthouse in 1940; the same thing happened at Stiffkey in 1946. Avocet chicks were seen with their parents in an Essex locality in 1944. The beginning of successful re-establishment came in 1947, when four pairs reared eight young at Minsmere in Suffolk, and another four or five pairs brought up another eight chicks at Havergate Island, on the same stretch of coast. Intensive measures were taken for the safeguarding of both small colonies at once by local ornithologists and the Royal Society for the Protection of Birds; the Society leased Minsmere and watchers were enrolled for daily duty throughout the breeding season.

In 1948 the birds abandoned the Minsmere site, but returned to Havergate and became established at another site in the same district. A total of about twenty-three young birds was reared in that year. The R.S.P.B. then purchased Havergate Island and from that time onward spared no effort in repairing embankments, controlling the water level, destroying predatory rats, and organising a constant watch on the 100-acre sanctuary.

In 1949 seventeen pairs reared thirty-one young, and in the following year twenty-one pairs brought up over forty young successfully.

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Turning the eggs.

(Above) The parent assisting the young to hatch.
(Below) The first chick has hatched.

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progress continued with few setbacks until the great
ault by the sea threatened Havergate with disaster early
year. Repairs to the banks were undertaken hurriedly
pumping removed the accumulated flood waters just
me for the avocets to find something like a hospitable
me when they returned in April. The appearance of
ground after its drowning was that of a barren waste,
the birds soon showed that they were finding plenty of
crustacea and other suitable food. The latest report
the number of breeding pairs occupying this area in
present season as forty, exactly the same as in 1952.

has been suggested that flooding and other disturb-
es of nesting avocets in Holland during the last war
have induced some of the birds to look elsewhere for
itable breeding-grounds. Be this as it may, the achieve-
nt of British ornithologists in nursing the pioneer
onies on the Suffolk coast marshes deserves the highest
ise; but for the high sense of responsibility shown by all
cerned, the birds' attempts must have proved abortive.

bservers have already reaped a rich reward in new
owledge of the finer details of individual and mass
haviour in these highly specialised birds; of nest-siting,
ation in eggs, incubation, care of the young and the
elopment and behaviour of fledglings. As the number of
ds increases, no doubt it will be found possible to learn
re from controlled experiments not undertaken earlier
reasons of safety.

THE ADVANCE TO SUPERSONIC FLIGHT

J. BLACK
M.Sc., Ph.D., A.F.R.Ae.S.
Dept. of Aeronautical Engineering, University of Bristol

This year is the fiftieth anniversary of the first flight of the Wright Brothers—a flight that lasted a minute at an average speed of 30 m.p.h. Thus within a lifetime the evolution of the aeroplane has brought us to the era of supersonic flight. In contrast to the almost lone efforts of the Wrights, who had first to carry out their own aerodynamic investigations before building the machine, supersonic flight has been preceded by vast research programmes, involving the use of complex and large-scale facilities, in many parts of the world. Yet even with all the information now available to the aircraft designer, the attainment of piloted level flight at speeds greater than sound will represent, when one takes into consideration the magnitude of the problems to be surmounted, as great an achievement as man's first flight.

The great need for scientific endeavour connected with high-speed flight arises largely from the changing nature of the airflow as the speed increases. At low speed the pressure changes produced in the airstream in flowing past an aeroplane in flight are so small compared to atmospheric pressure that no appreciable compression occurs and the density of the air remains unchanged: the aircraft is travelling through a fluid which effectively resembles water. Above speeds of about 500 m.p.h. at sea-level, however, the pressure changes are sufficient to produce local regions of compression and rarefaction, and the air then behaves as a gas. It is not surprising, therefore, that many additional problems are created when a body flies in a gas; these may require novel means of solution, which need not necessarily be related to those used in the earlier days of flight in the more simple 'incompressible' air. For these reasons the science of the aerodynamics of high-speed flow is often treated as a separate subject, known as gas dynamics.

Compressibility phenomena were studied long before an aeroplane ever left the ground; the ballistic experts of the 19th century had improved the flight of shells and bullets by making the noses of the projectiles much more pointed. This improvement was found to be associated with the beneficial effect of the sharp nose on the compression of the air immediately ahead of the projectile. The now familiar term *Mach number* commemorates the pioneer work which the Austrian physicist and philosopher, Ernst Mach, did in this field; some of his papers published about 1890 even included photographs of the compression waves produced by shells in flight.

Aeronautical scientists first became concerned with compressibility about forty years after Mach's outstanding experiments, when the serious fall-off in performance of propellers of aircraft flying at the then maximum speed of about 300 m.p.h. was traced to unusual air flow at the propeller tips, which were moving through the air at speeds near to that of sound. Some classic theoretical papers (notably those of Glauert and Ackeret) date from that period. With the subsequent rapid increase in aircraft speed, and especially since the advent of jet propulsion, modern aircraft suffer from the various phenomena associated with local regions of compression and rarefaction on the wings, round cockpit canopies and at other points of marked curvature. At supersonic speeds, as we shall see later, the whole conception of the aeroplane is dominated by these phenomena.

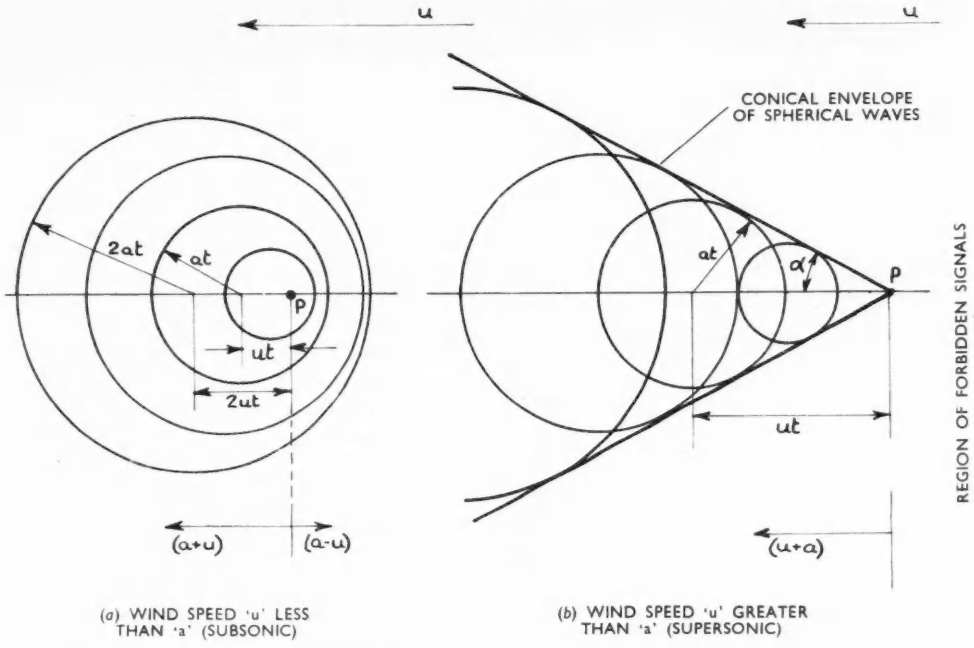
Before we can examine the influence of compressibility on the shape of the aircraft, there are some basic ideas about the flow of air at high velocities which we must first understand.

SPEED OF SOUND AND MACH WAVES

Weak pressure pulses in air are propagated with a wave velocity that depends only on the air temperature; since sound is one particular manifestation of these pressure waves, we use the term 'speed of sound' as a more concise description for the speed of propagation of weak pressure disturbances. Thus if we have a point source of disturbance in air, spherical waves will be emitted from it, travelling with a speed of a feet per second, which at 15°C., the standard temperature at sea-level, is 760 m.p.h. This wave system may be compared to the circular ripples spreading across the surface of a pond from a point where a succession of ball-bearings are dropped into the water.

Now imagine that these ball-bearings are being dropped, not into still water, but into a stream which is flowing with a velocity of u, which is less than a (Fig. 1*a*). This is analogous to disturbances being propagated in a wind of speed u, or if the air is at rest, to the disturbances from a source travelling with subsonic speed u. Then after time, t, the wave will have expanded to radius at, while at the same time its centre will be carried downstream a distance ut. Thus the wave will have various velocities relative to point P in different directions, ranging from a minimum of $a-u$ directly upstream to a maximum of $a+u$ directly downstream. The disturbance at P will therefore be able to make its presence felt throughout the whole field of flow, even though the pulse, which can be regarded as the signal of the presence of the disturbance, e.g. a small obstruction, may take longer to penetrate a given distance upstream than to travel the same distance downstream.

Consider what happens when u is greater than a, that is, supersonic flow (Fig. 1*b*). After time, t, the radius of the wave will be at as before, but the centre will have been carried downstream a distance ut greater than at. The spherical waves will thus be contained within a conical envelope lying downstream, with vertex at P, the angle of the cone being determined by the ratio $\left(\frac{u}{a}\right)$. This ratio of the speed of flow to the speed of sound is the *Mach number*



(*a*) WIND SPEED 'u' LESS THAN 'a' (SUBSONIC)

(*b*) WIND SPEED 'u' GREATER THAN 'a' (SUPERSONIC)

FIG. 1. Sound wave propagation from point source of disturbance *P* in air moving at subsonic and supersonic speeds.

(M), and the conical sound wave is called the *Mach wave*. The most striking feature of the supersonic flow (M greater than 1·0) is that the disturbance at *P* can no longer send a signal upstream of itself, but can only affect the region within the Mach cone; the upstream region has been vividly called the region of 'forbidden signals'.

Wave propagation systems similar to those in Fig. 1 will be produced if instead of *P* being fixed in a stream of velocity *u*, it is regarded instead as a disturbance source moving forward into air at rest with a velocity of *u*. It is only the relative motion between *P* and the air which affects the velocity components of the waves.

SHOCK WAVES

A basic phenomenon of supersonic flow is the shock wave. This shock wave is a consequence of the inability of a body to warn the supersonic stream approaching it of its presence. Thus in contrast to subsonic flow, in which the stream receives warning of the presence of the body and is prepared to divide and flow smoothly past the nose of the body, the air in the supersonic stream 'piles up' ahead of it. This 'piling up' occurs in a narrow region of intense compression; and it is only after traversing this region that the air can flow round the body.

This discontinuity in the flow always occurs in an abrupt manner, and consequently it is termed a *shock wave*; after passage through it, the velocity of the airstream is reduced, while its pressure and temperature are increased.

An analogy can be drawn between the shock wave and a

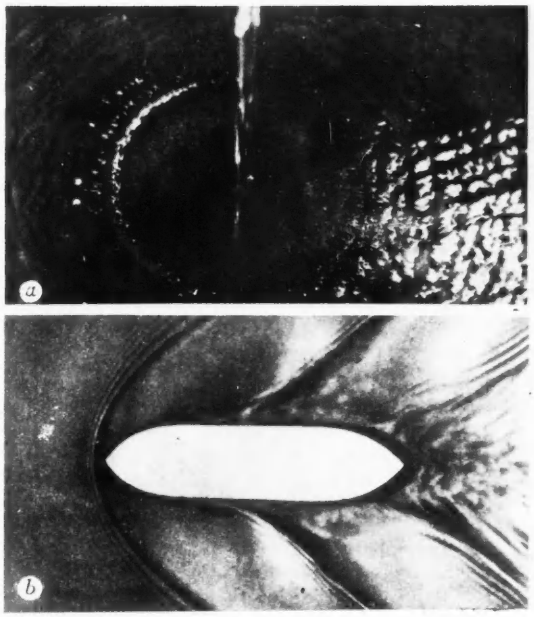


FIG. 2. The hydraulic analogy to supersonic flow.
(*a*) Circular 'hydraulic jump' formed when a jet of water hits a flat surface.
(*b*) The bow-wave and jumps formed in water flowing past a model bridge pier.

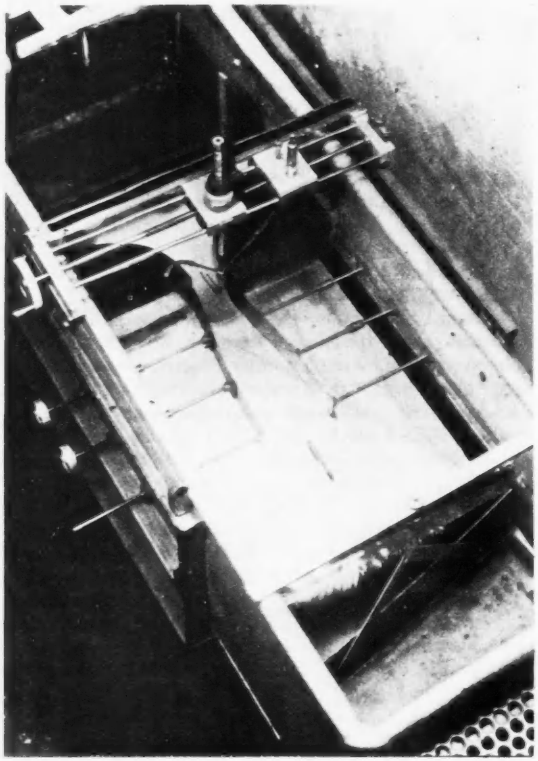


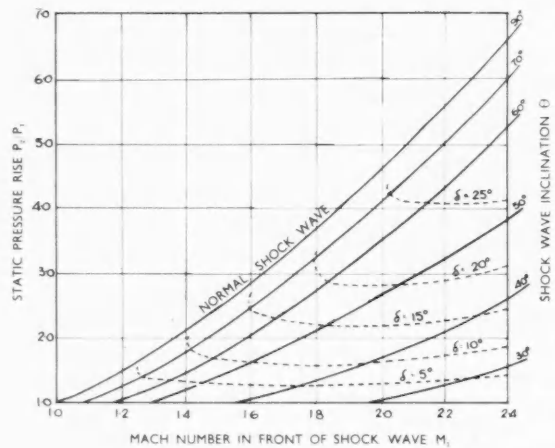
FIG. 3. The hydraulic analogy apparatus used in Bristol University's Department of Aeronautical Engineering. A model aerofoil is placed in the shallow flow of water pouring out of the diverging nozzle. The pattern of hydraulic jumps produced by the model resembles the shock-wave system on an aerofoil model in a supersonic airstream.

phenomenon that occurs with flowing water. Fig. 2*a* shows a jet of water hitting a flat surface; the water spreads out radially in a thin sheet, then suddenly increases in depth to give the effect known as the 'hydraulic jump'. In the flow past a bridge pier (Fig. 2*b*) the jump manifests itself as a 'piling up' of water in an almost spherical bow wave ahead of the pier (compare this with the shock wave ahead of a sphere, Fig. 7); the bow wave ahead of a ship is a similar phenomenon. This analogy between water flow and gas flow has been developed to quite a high degree of accuracy, and special 'hydraulic analogy' water channels, in which supersonic flow may be accurately simulated with a shallow flow of water, have been built. Fig. 3 shows such a 'poor man's supersonic wind tunnel', with a double-wedge supersonic aerofoil placed in the working section at the nozzle exit.

Shock waves may lie at any angle to the airstream, depending on the conditions of the flow and the angle at which the stream hits the deflecting surface. The dependence of the pressure rise through a shock wave on the deflection can be seen in Fig. 4. At a Mach number of 2 a shock wave perpendicular to the flow increases the pressure 4½ times, whereas an oblique shock wave inclined at an angle of 45 *to the flow* (as is produced by the flow past a wedge of semi-nose angle δ of 15) only produces the smaller pressure rise of 2·2. This fact suggests immediately that a body which has to travel at supersonic speeds should have as sharp a nose as possible, because it will then have oblique shock waves lying back from the nose, and therefore it will have a reduced pressure rise to cope with. The pressure behind the wave acts against the frontal area of the body, and so produces *drag*, to use the technical term for this type of resistance to motion; consequently, the smaller the pressure rise through the nose shock waves, the lower the drag. The influence of this consideration on design is discussed later.

SUBSONIC AIRCRAFT

A body does not necessarily have to be travelling at supersonic speed in order to suffer from shock waves. This is not a contradiction of my earlier statement that shock



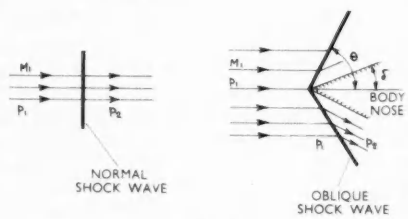


FIG. 4. Pressure rise through shock waves. (*a*) The normal shock wave lies perpendicular to the flow. (*b*) A sharp-edged body of semi-nose angle δ deflects the flow, and the shock wave then lies obliquely to the flow at an angle θ.

waves only arise in supersonic flow, but follows from the fact that since there are curved surfaces distributed on an aircraft (e.g. the wing surfaces, cockpit canopies, etc.), there must be local regions of accelerated flow, where the airstream has to traverse the curves. The induced velocity in these regions may be about 1·5 times the velocity of the free stream approaching the wing.* Hence on an aeroplane travelling at, say, M=0·75 (570 m.p.h. at sea-level) there will be local regions of supersonic flow towards the front of the wing surfaces, and shock waves will form where this flow has to decelerate as it approaches the trailing edge.

Fig. 5 illustrates the growth of these shock waves on an aerofoil as the speed increases from M=0·6 to 0·87. (These photographs are taken with a 'schlieren' optical system; here the dark regions denote compression, while light regions denote expansion.) It will be seen that disturbances gradually develop, first on the upper surface, which coalesce as the Mach number increases, until the intense region of compression of the shock wave, as indicated by the narrow black band, is formed. Note how the flow at the base of the shock wave is seriously affected; this results in the thickening of the boundary layer of air, and at the higher Mach numbers, in its breakaway from the surface.

The widening of the wake behind the aerofoil indicates an increase in drag. The lift of the section actually increases at first, in spite of the shock wave formation, until the shock wave on the lower surface moves farther aft than the wave on the upper surface. When this occurs there is a serious loss of lift.

Another serious consequence of this shock wave formation can be severe buffeting of the wing, as was dramatically portrayed in the film *The Sound Barrier*. There is also a loss of control, because the control surfaces (e.g. ailerons, elevators) are mounted at the rear of the aerofoil, and are thus downstream of the shock wave. As we saw earlier, there is no mechanism whereby a body can affect the flow upstream of itself in supersonic flow, and so deflection of the control, which normally acts by affecting the flow forward over the whole aerofoil, has very little effect. The pilot's control over the aircraft is consequently considerably reduced.

The forward speed at which the drag suddenly rises is termed the *critical Mach number*; on war-time fighter aircraft it was about 0·7, but it has been raised considerably for the latest aircraft by refinements in design. Two methods have proved fruitful; thinning the aerofoil section so that its maximum thickness is less than 10% of the chord (distance from leading edge to trailing edge), compared with the

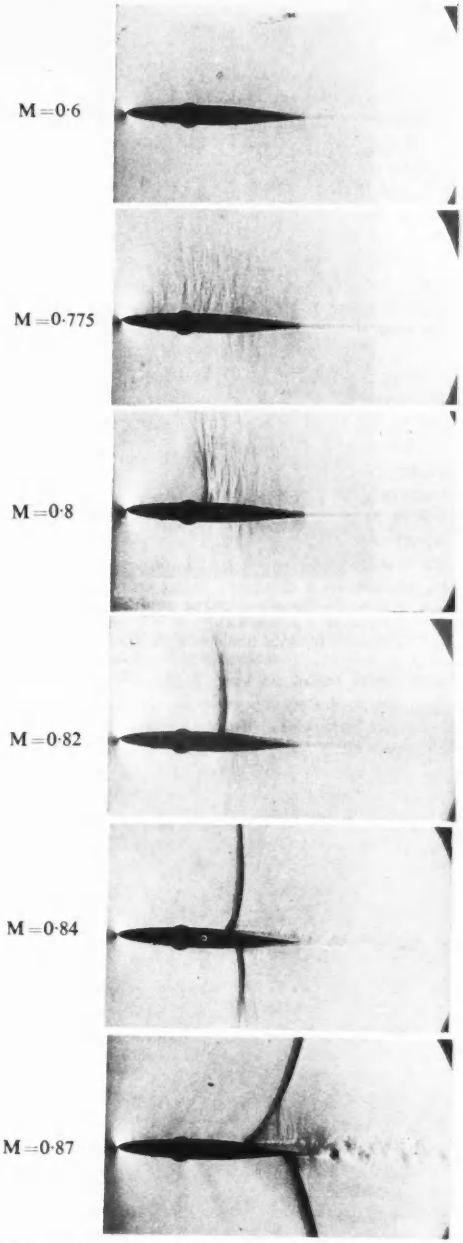


FIG. 5. Schlieren photographs of the growth of shock waves in the subsonic flow of air past a 10% thick aerofoil. The adverse effects of the shock wave on the flow adjacent to the surface, and the consequent thickening of the wake behind the aerofoil, can be clearly seen. With increase in Mach number the shock waves have moved aft towards the trailing edge. (Photographs taken in a high-speed wind-tunnel in the Aerodynamics Division of the National Physical Laboratory. The circular bulges near the mid-chord are shadows of the model support trunnions, and are not in the flow.)

* As mentioned earlier, in connexion with the wave system from a point source of disturbance, it is immaterial whether we consider the real case of air at rest, with a body travelling through it, or whether we change our point of observation and travel with the body, so that relative to the observer the body is at rest, and the air is rushing towards it. The flow pattern and behaviour is a function only of the relative motion between the air and the body. Aerodynamicists tend to think in terms of the latter reference system, since to them it represents the situation in experimental aerodynamics. In a wind-tunnel test the body to be investigated is mounted rigidly in the working section of the tunnel, and the air is set in motion. They relate their observations, therefore, to the velocity of the free stream of air coming down the tunnel, approaching the model.

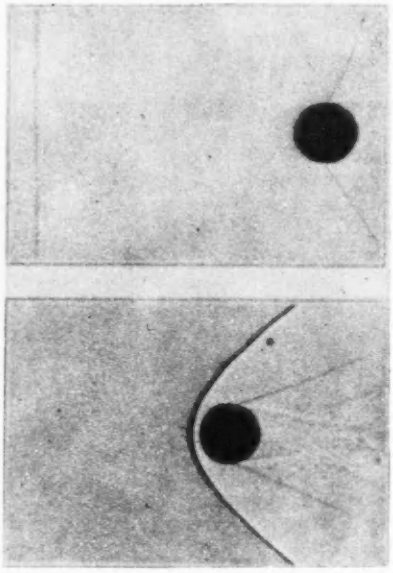


FIG. 6. The shock wave produced by a sphere in flight as it accelerates from the speed of sound (*top picture*) to twice that speed (*bottom*).

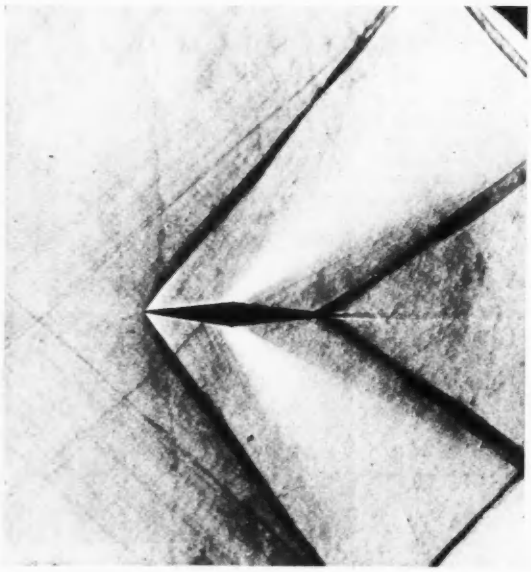


FIG. 7. The shock waves and the expansion regions round a 12% thick double-wedge aerofoil at zero incidence in an airstream at a Mach number of 1·6. Shock waves lying obliquely to the flow extend from the leading and trailing edges, and there is a fan-shaped region of expansion extending from the corner at mid-chord.

more conventional 15% figure common ten years ago; and sweeping the wing back to form arrowhead wings. (There are variations of the latter, such as delta or crescent wings.) For example, if the critical Mach number of an aircraft with a straight wing is 0·75, and the wing is swept 45°, the critical Mach number of the aircraft is raised theoretically to about 1·06. In practice it may only rise to 0·9, but this gain still offsets the extra structural complexity and the difficulties that sweepback introduces in matters of control and stability.

SUPERSONIC FLIGHT

When a body travels at supersonic speed, a system of shock waves different from that prevailing at subsonic speed is produced. If the nose of the body is blunt, a spherical shock wave is formed ahead of the body; the growth of this wave ahead of a sphere in flight can be seen in Fig. 6. At sonic speed the wave is very far ahead of the body; as the sphere accelerates the wave moves closer to it, but still remains detached and slightly ahead of it. With a sharp-nosed body the shock waves are attached to the nose, and lie obliquely to the flow, once a certain speed (dependent on the nose angle) is attained. When travelling at lower speeds, the shock wave is detached and ahead of the nose; the Mach number for a particular nose angle at which the shock is just detaching is termed the *detachment Mach number*.

As explained earlier, it is desirable to have the nose shock waves oblique to the flow, since the pressure rise through the waves is thereby reduced. In designing a fuselage or wing for a given supersonic speed, therefore, we must choose the nose angle so that the waves will be attached at the design Mach number; for example, at M=2·0 the fuselage nose must be a cone with semi-angle of less than 40° and the wing section leading edge must be a sharp-edged wedge of semi-angle less than 22½°. The supersonic aerofoil section is thus quite unlike the subsonic aerofoil shown in Fig. 5; since it has to have sharp leading and trailing edges, the supersonic aerofoil becomes in its simplest form a double wedge. The shock wave system on such an aerofoil section consists of two oblique shock waves extending from the leading edge, with another two extending from the trailing edge (Fig. 7). Where the air passes over the corner formed at the point of maximum thickness there exists a region of expansion, indicated by the 'white fan' in the schlieren photograph.

THE TRANSONIC REGION

The two distinct régimes of flow, subsonic and supersonic flight, have been discussed, but the supersonic aircraft must obviously pass through subsonic and sonic speeds in attaining supersonic speeds. The transonic speed region from about M=0·9 to M=1·1 presents many difficult problems.

The worst of these is the rapid rise in drag (illustrated in Fig. 8 for wings with zero sweepback and 45° sweepback flying at 40,000 feet, where the speed of sound is 660 m.p.h.). When travelling at this speed, the drag of the straight wing increases almost tenfold, calling for an immense increase in propulsive thrust, which at present

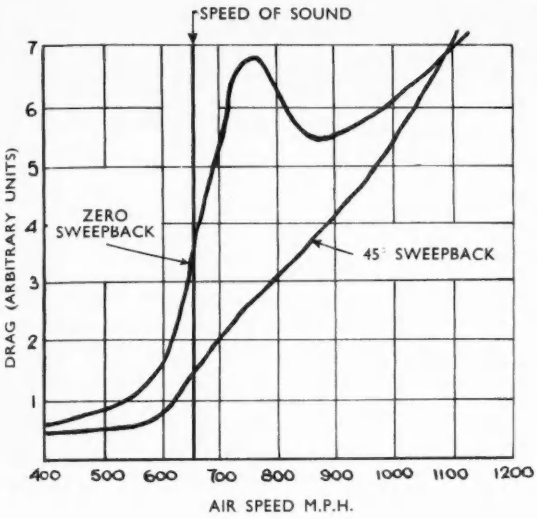


FIG. 8. The drag rise in the transonic region for straight and sweptback wings of equal area at 40,000 feet.

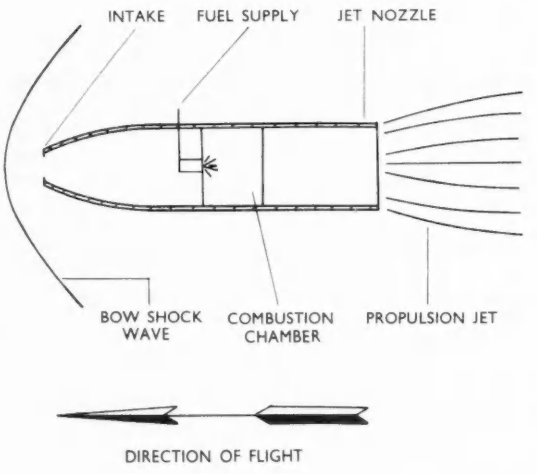


FIG. 9. Diagram of ram-jet unit.

can only be provided for a brief period with rockets. Alternatively, the aircraft can be put into a steep dive, and thus gain enough kinetic energy to overcome the large drag momentarily.

The beneficial effects of sweepback in the transonic region can be appreciated from Fig. 8; the drag rise is considerably reduced around 700 m.p.h. but then climbs more steeply, so that at 1100 m.p.h. (M=1·68) there is no further advantage over the straight wing. (On the contrary, the reverse is true and a straight wing is then preferable.)

A typical example will illustrate the significance of the drag rise shown in these curves. For an aeroplane requiring about 8500 h.p. of thrust at a speed of 645 m.p.h. at sea-level (M=0·85) the thrust required at 1280 m.p.h. at sea-level (M=1·68) will rise to about 140,000 h.p. At 40,000 feet, however, the same Mach number (1·68, corresponding to a speed of 1100 m.p.h.) will only call for the modest figure of 20,000 h.p. This reduction of thrust required with altitude explains the present trend to fly higher and higher, but even so the power required is still far beyond the present achievements of turbo-jet engines.

A new form of propulsion is likely to be used at these speeds. This is the *ram jet* shown in Fig. 9. In its essentials, this is by far the simplest form of propulsion unit, except for rockets, since there are no moving parts. It will be remembered that a shock wave produces a large rise in pressure behind itself (Fig. 4); if a hollow duct travels at supersonic speed, the shock wave formed ahead of the nose will compress the air and raise its temperature. In the ram jet fuel is sprayed into this compressed air, and the expansion of the burning gases produces a propulsive jet out of the tail pipe. In spite of its apparent simplicity, the ram jet still requires many years of development before it is a safe, practical means of propulsion.

Looking again at Fig. 8, it may be asked how these drags at transonic speeds can be estimated, since it is impossible as yet to make accurate tests in a wind tunnel at transonic speeds. Some measurements have, however, been made using free-flight techniques. These consist of dropping a test vehicle from a great height or firing it off the ground with rockets; this vehicle carries the appropriate wing model which is undergoing tests, and all the forces acting on the model are converted by electronic apparatus in the vehicle and telemetered to ground stations during the projectile's flight. At the same time, the vehicle is followed with ciné-theodolites and radar, which provide records from which its speed can be determined.

In addition to the aerodynamic problems of supersonic flight, there are considerable structural difficulties. The wings must have sharp leading and trailing edges, and a maximum thickness of less than 10% of the chord; this calls for the use of very shallow spars, which nevertheless have to carry the extremely large loads. A further complication is the heating of the fuselage nose and wing leading edges due to the compression of the air where it is brought to rest; at a speed of 1000 m.p.h. this produces a temperature rise of about 100° C. The strength of conventional aircraft materials, such as aluminium or magnesium alloys, falls considerably with increase in temperature, and they may be too weak to be used under these adverse conditions. New materials will therefore be required, and aeronautical engineers are keenly interested in the potentialities of titanium alloys for this reason. It is interesting to note in passing how the needs of aeronautics may again bring into common use a material which otherwise might remain merely a metallurgical novelty.

RADIO-ISOTOPES IN BIOLOGY

J. G. FEINBERG
B.S., M.S., D.V.M.

The application of tracer techniques using radio-isotopes and heavy stable isotopes (such as deuterium) to follow the fate of chemical elements in the bodies of animals and plants has resulted in the solution of numerous problems that were virtually insoluble hitherto. In this article Dr. Feinberg, author of "The Atom Story", *describes some of the outstanding successes to the credit of isotope techniques.*

The isotopes have been called the most important scientific tool developed since the microscope. To attempt to describe the overall contribution they have made to the science of biology would be, even at this early date, almost as monumental a task as that of describing the contribution of the microscope to the science of medicine. In a short article little more can be done than to give some appreciation of the impact of isotopes on biology and the course isotope research is taking.

The rise of isotope techniques has given a new impetus to the biological sciences. In many cases where research had become bogged down, or come up against a blank wall, and progress seemed confined to (more or less) inspired guesses, the rapid development of these techniques, consequent upon the increased availability of a wide range of isotopes of recent years, has enabled biologists to surmount obstacles and resume their advance. The newer knowledge thus gained has frequently been totally unexpected, and sometimes it has been in flat contradiction to the aforementioned 'inspired' guesses.

One classical example of this is found in the early isotope researches of R. Schoenheimer and D. Rittenberg, who investigated the use made of foodstuffs by the animal body. Before these scientists brought the isotopes of hydrogen and nitrogen to bear on the problem, it had been assumed by physiologists that the adult body was a relatively stable structure and that the only function of food was to provide energy and such materials as might be needed for repair or replacement of damaged or worn-out tissues. One of the fundamental concepts of physiology had long been that of 'endogenous' and 'exogenous' dietary nitrogen, the former used for tissue replacement and repair, the latter supplying energy in its hasty passage through the body. These ideas seemed reasonable in the light of experiments on metabolism and excretion. There was really no way of knowing, once they had entered the body, which hydrogen, nitrogen or carbon was which. So much of each element was put into the body, so much was observed to come out in the excreta. It was natural to assume that that which came out was largely the major fraction in the food not immediately required for tissue building.

When Schoenheimer and Rittenberg used isotopic forms of hydrogen and nitrogen—forms they could invariably identify, no matter what their fate in the animal body or where they turned up—they discovered that the concept of the chemically static body was nonsense. When they fed an animal fatty acids containing deuterium (D, H^2), they found that instead of the deuterium being excreted quickly in the waste products of fat metabolism, most of it ended up in deposited fats throughout the animal's body. Even when the animal was on a semi-starvation diet and so desperate for energy it was burning its own body fats, the deuterium-labelled fatty acids in the food still wound up in the fat deposits while the body fats continued to be burned. With N^{15}-labelled amino-acids a similar state of affairs was found to prevail among the nitrogenous tissues. The labelled amino-acid was quickly taken up and stored away in the body proteins. This was followed by an exchange of amino groups between it and the other amino-acids, so that eventually some molecules of all the amino-acids (with the exception of lysine) contained N^{15} amino groups. This was the death knell of the 'endogenous-exogenous' concept of nitrogen metabolism.

As a result of the isotope research we now understand the body is not, as was formerly conceived, a static structure which treats its foodstuffs with, depending on the needs of the moment, more or less detachment. The body has emerged as a dynamic chemical system in a constant state of flux and interaction with its environment. Chemical elements (with the striking exception of iron) which enter it are quickly exchanged for its own constituents and rapidly built into the body fabric. This is a discovery of fundamental importance, yet one which would probably never have been made had it not been for the entrance of isotopes into the biochemical laboratory.

THE SENSE OF 'TRACE'

Only through the use of distinctive isotopic forms of the biologically important elements has it become possible to follow the course of a specific atom or group of atoms through the intricate pathways of a biological system. In a way the isotopes have endowed the biologist with a sort of additional sense. One might call it a sense of 'trace'—a sense for picking up the track of a particular atom and following it through a series of biological adventures. And it is none the less real for being an extra-corporeal sense, lodged in the biologist's laboratory instruments.

This ability to trace isotopes through natural biological processes is based on the greater discrimination in the matter of atomic forms exercised by the biologist than by the biological systems which he studies. 'Isotopes', as every schoolboy knows, is the generic name given to different atomic forms of the same element. The *chemical* characteristics of isotopes of the same element are, on the whole, virtually identical: it is in physical properties that they differ. They all differ in weight; many also differ in the stability of their nuclei. Those which have unstable nuclei are the radioactive isotopes, shooting out tell-tale rays in the process of achieving stability.

With certain qualifications in the cases of deuterium and tritium (T, H^3), biological processes do not distinguish

between the chemically similar, though physically dissimilar, isotopes of an element. The scientist does—with his mass spectrograph to separate elements according to their weights, and his Geiger-Müller counter, sensitive photographic plates and other devices to detect atomic rays. Biological isotope research thus consists of feeding an uncommon isotope of an element into a biological system, following its course and noting its fate. Whatever the system does with the isotope, it is doing with the commoner form of the element it normally encounters. In this way the scientist can determine the place of any particular element in the chemical economy of a biological system.

A LABELLED VITAMIN

In many cases the biologist is interested in the fate of a chemical group or compound rather than that of a particular element. He then uses an isotopic form of one of the elements in the group or compound as a distinguishing tag. If of a simple chemical nature, such as phosphate for fertiliser studies, the compounds are made in the chemical laboratory. In other cases it may be simpler—or, indeed, necessary—to allow a living organism to manufacture the compound from isotopes placed at its disposal. An example of the latter is the work done by E. Lester Smith on metabolic studies of isotope-labelled vitamin B_{12}. Radioactive isotopes of cobalt and phosphorus were included in the culture medium on which *Streptomyces griseus* was grown, and this organism obligingly incorporated them into the vitamin B_{12} it synthesised. The tagged vitamin was then followed during its absorption and subsequent metabolism in animals and humans.

The stable isotopes, which differ only in weight, commonly occur in minute proportions in nature, and these were amongst the first to be concentrated and used in biological research. It was the isotopes H^2 and N^{15} (as against the more common H^1 and N^{14}) which Schoenheimer and Rittenberg used in demonstrating the dynamic pool of chemical substances in the body.

Radioactive isotopes of the biologically significant elements are, with the exception of radio-potassium (K^{40}), non-existent in nature. Fortunately, such isotopes can usually be prepared by subjecting stable atoms to bombardment with neutrons or deuterons in atomic reactors or cyclotrons. The bombarded atoms capture particles and, if the resulting nucleus is stable, become heavy stable isotopes. Otherwise they become radioactive isotopes. Today it is possible to make over 600 isotopes to order. Over a hundred can be conveniently prepared simply by 'cooking' elements in an atomic reactor.

What use can the biologist make of them? In the words of one author, M. D. Kamen: "The ramifications made possible by labelling techniques are beyond the imagination or knowledge of any single writer." However, certain broad patterns in the biological application of isotopes are discernible.

Metabolism and biosynthesis—how a living organism uses its foodstuffs to provide itself with energy and synthesise its own peculiar compounds—are naturally among the chief concerns of the biologist and in these fields he has found the isotopes most useful. In particular, a great deal of isotopic study has been carried out on photosynthesis.

THE STUDY OF PHOTOSYNTHESIS

Photosynthesis is the basic biochemical process underlying all life, since it provides the ultimate source of food for all living things and replenishes the oxygen in the atmosphere. It is the chain of chemical reactions in which green plants use the sun's energy to build up energy-rich carbohydrates, proteins and fats from inert carbon dioxide and water, releasing oxygen in the process. With a better understanding of photosynthesis, man may conceivably find a new way of increasing the world's food supply: either by duplicating the photosynthetic process in the laboratory or by channelling photosynthesis in the plant into the production of vast quantities of carbohydrate and fat for food or for conversion into synthetic fuels.

Formerly biologists were severely handicapped in their study of photosynthesis. Disruption of the living cell immediately stops the process. In the living cell they could not tell one carbon atom from another and so could not follow the chemical fate of carbon dioxide once it entered the plant. The availability of the radioactive form of carbon known as carbon 14 changed all that. By exposing a green plant to $C^{14}O_2$ in the presence of sunlight and then separating the compounds in the plant, identifying them and checking them for C^{14}, biochemists could determine what compounds the plant was making from carbon dioxide. By gradually shortening the time of exposure they could determine the pathways followed by photosynthesis.

This problem was tackled by scientists at the University of California Radiation Laboratory. They exposed plants to carbon dioxide tagged with C^{14} for one minute, and then immediately cut short photosynthesis by dropping the plant into liquid nitrogen. The photosynthesised compounds were then extracted with boiling alcohol, and separated chromatographically. At least fifty compounds were found tagged with radio-carbon; which meant that within the space of one minute photosynthesis was capable of producing more than fifty different compounds from carbon dioxide! By cutting the exposure time down to two seconds the scientists were able to stop photosynthesis after only two or three tagged compounds had been formed. Ultimately they were able to pinpoint phosphoglyceric acid as the very first stable organic chemical a plant produces in photosynthesis. Other early products are derived from phosphoglyceric acid by biochemical reactions, which eventually lead to the 6-carbon sugars ($C_6H_{12}O_6$) and other compounds essential to the plant. After two minutes of photosynthesis, radio-carbon tags appeared in numerous amino-acids and even in proteins and fats. With such rapidity does photosynthesis convert simple, inert carbon dioxide into complex, vitally active compounds and living tissues.

By studying the photosynthesis in algae and a whole range of higher plants by the isotope method it was found that the early stages of photosynthesis follow identical lines in all plants. Only later do the different plants diverge into the synthesis of their own characteristic compounds. With the knowledge thus revealed by isotope techniques, the scientists are already beginning to alter conditions to produce modifications in the proportions of end products. At the University of California it has been found possible to divert photosynthesis in one species of

green algae into the production of either a preponderance of sucrose or of malic acid simply by altering the acidity of the medium. At the Carnegie Institute of Washington the alga *Chlorella* which normally produces a large proportion of protein has been urged into the formation of abnormally high quantities of fat.

SYNTHESIS OF CHOLESTEROL

Even as isotopes have been unravelling some of the mysteries of photosynthesis in plants, they have been revealing some of the secrets of biosynthesis in animals—i.e. the building up of complex compounds from simple ones in the animal body. To give but one illustration, there has been a major assault on cholesterol synthesis in which the key workers have been J. W. Cornforth of Britain's Medical Research Council and Konrad Bloch of the University of Chicago. Cholesterol, a complex cyclic compound with a framework of 27 carbon atoms, is of profound biological significance as it is believed to be a precursor of such physiologically important chemicals as the sex hormones, the adrenal cortical hormones (including cortisone) and vitamin D. By using acetic acid tagged with deuterium, C^{13} and C^{14}, it has been shown that the body can rapidly build up the complex cholesterol molecule from simple acetic acid, with the latter two-carbon compound contributing all the cholesterol's 27 carbon atoms. In the laboratory, slices of rat liver will also synthesise cholesterol from salts of acetic acid. By using two types of tagged acetate—one which had a radio-carbon atom on the acid end, one in which the methyl carbon was radioactive—the biochemists found that the synthesis of cholesterol from acetate followed a definite pattern. Fifteen of the cholesterol carbon atoms came from methyl carbons of acetate molecules, twelve from acid carbons. So far sixteen of the cholesterol carbons have been individually traced to their points of origin in the acetic acid molecule. Radio-isotope research now going on should soon clear up the acetate origins of the remaining eleven.

In the field of metabolism, isotopes have become invaluable tools in working out the basic life processes through which the body derives its energy and builds up its tissues. Their use has revealed hitherto unsuspected metabolic pathways and shown that evanescent compounds which are hardly detectable are of the greatest importance as intermediaries in metabolism. Thus, while the entire body of a 100-gramme rat contains no more than a few milligrams of acetate at any time, its liver is found to produce over a gramme of acetate a day.

In such ways biochemists are investigating many vital phases of metabolism and biosynthesis. The lactating cow, which may be regarded as a high-powered biochemical factory, is a very useful animal for the study of the biosynthesis of fats, lactose sugar and proteins. Both at the University of California and at the National Institute for Research in Dairying at Shinfield, salts of fatty acids tagged with C^{14} have been injected into cows and the milk products analysed for labelled compounds. It has been shown that acetic acid is rapidly converted into the fatty acids characteristic of milk, whereas the higher acid radicals (e.g. propionate and butyrate) are more important for the synthesis of lactose, playing a minor role in the building of fatty acids.

The transport of substances into and through living organisms is a function especially amenable to radio-isotope investigation. Phosphorus 32, which is radioactive, has proved extremely valuable in the study of the availability of phosphate fertilisers to plants. An American agricultural authority has said: "The advances made during the past four years with isotopes in the knowledge of phosphate fertilisers is equal to and may exceed the progress in this field during the preceding 50 years." With superphosphate tagged with P^{32} Swedish investigators have shown that the phosphate in this fertiliser becomes available to plant roots almost immediately it is added to the soil. Using a similar technique, American investigators have discovered that pasture grasses adequately take up broadcast superphosphate through their leaves and roots; from this the conclusion is drawn that old pastures can be rejuvenated without any necessity for ploughing. They also found that plants differ in their utilisation of fertiliser phosphate. Corn takes up phosphate from fertiliser only during its early stage of growth; later in the season deep-reaching roots draw mainly on phosphorus already in the soil. The same is true for sugar beet. Fertiliser spread late in the season is of no value to these crops. On the other hand, potatoes rely heavily on fertiliser phosphate during their entire growing season and can profit from late superphosphate applications. Following the course of P^{32} has also demonstrated that phosphoric acid added to irrigation water is just as effective a fertiliser as superphosphate spread dry on the soil, and that the phosphorus of green manure is almost as accessible to growing plants as is that in superphosphate.

The study of the movement of other minerals in plants has often yielded surprising results. 'Dormant' trees, for example, have been found to be not so dormant as thought. Radio-potassium was painted on a lateral branch of a 'dormant' plum tree when there was 30 degrees of frost and the sap was therefore presumed to be immobile. Within 48 hours the radio-potassium had moved 18 inches up the branch and 18 inches down it. In other 'dormant' trees placed in greenhouses at summer temperatures potassium tags moved right down to the roots in 26 hours. Studies such as these will find application in solving problems of plant nutrition and nutritional disorders—e.g. chlorosis. Radio-isotopes are also helping in the development of techniques for protecting crop plants against insects, fungi and the competition of weeds. Tagged insects and airborne fungi are followed and their dispersion patterns mapped. Radio-iodine has been used to plot the pathways of spread of the oak wilt fungus along the roots of oak trees, and how it spreads from one root system to a neighbouring system. In the eucalyptus forests of Australia, where mistletoe has no romantic association but is a costly parasite of the eucalyptus trees, radio-isotopes are being used to study the way in which the parasite preys on its host.

Systemic phosphorus insecticides tagged with P^{32} have made possible studies which revealed that plant leaves absorb the insecticides principally through their undersurfaces and that efficient absorption takes place only

during the day. By tagging the selective weedkiller, 2, 4-D, with radio-carbon, it was possible to demonstrate that the broad-leaved plants, which are susceptible, absorb and translocate so much of the weedkiller within two hours as to become uniformly radioactive. Contrariwise, the resistant narrow-leafed grain and pasture grasses absorb very little and translocate even less.

The study of the transport of water through the animal body has received a terrific impetus from the application of deuterium- and tritium-tagged water. The use of $H^2{}_2O$ and $H^3{}_2O$ has made possible observations which could otherwise not have been made because of the inability to distinguish one H_2O molecule from another. With the isotope-tagged water molecules many remarkable observations have been made. The water vapour in inspired air is exchanged almost 100% with the fluid in the lungs. The skin is a permeable structure through which water vapour may diffuse in either direction. The exchange between water in the blood and that in such structures as the eye and cerebro-spinal canal is so fast that within a few minutes to an hour or two there is a complete turnover of fluid in the organs. The rate of exchange of tagged water between the blood and the body tissues is so great that more water passes in and out of the blood every minute than the total fluid volume of the blood.

I have now exhausted my space, but I have not exhausted my subject; in fact I have barely scratched its surface. Entomologists are feeding insects radioactive meals and following them in the course of their migrations. Immunologists are using tagged antigens to study immunological mechanisms. Virologists are labelling viruses and hosts in an effort to elucidate virus development, their mode of attack and their relationship to the tissue constituents of the host cells. In fact, the field of application of radio-isotopes to biological problems is almost as wide as biology itself. From such a welter the selection of more than a few brief, illustrative examples would invariably have led to a mere recital of isolated experiments. By choosing the few examples used in this article I have tried, instead, to give a broadly integrated picture of the contribution the isotopes are making to our fundamental knowledge of life and the relationship of living things to each other and to their environment.

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LIND AND HIS "TREATISE OF THE SCURVY"

HARRY HOGGAN

M.A., F.R.S.E.

An international conference, organised by the Nutrition Society, was held in Edinburgh in May to commemorate the bicentenary of the publication of James Lind's *Treatise of the Scurvy*. This famous book was first published in 1753 and ran to three editions inside twenty years. To mark the occasion the Edinburgh University Press has prepared a new edition,* which contains a reprint of the original treatise and also includes several additional notes by famous medical scientists on modern aspects of scurvy.

Lind's *Treatise* is a classic account of the methods employed to deal with a specific medical problem, in this case a dreadful disease which previously had cost thousands of lives every year. Lind described the disease exactly as it is known today: the sufferer feels tired and listless, the teeth may become loose, the gums become itchy, swell and bleed easily, small red spots appear on the skin from tiny points of bleeding which may result in large bruises from minor injuries, wounds become septic, and death may come suddenly after some trivial exertion. His book was dedicated to Lord Anson (1697–1762), the 'Father of the British Navy', who had had bitter experience of the ravages wrought by this terrible scourge. In June 1740, Anson, as commodore of the Navy's S. American squadron, had sailed from Portsmouth with six ships and over 2000 men to challenge Spanish supremacy in the Pacific. He returned in 1744 with one ship and a wealth of booty—but only a hundred of his men survived. Nearly all who perished, died not in battle or by shipwreck, but from scurvy. James Lind (1716–96), an Edinburgh doctor serving in the British Navy, was appalled by this tragic loss of life.

Three years later he carried out his famous experiment, the first real clinical experiment of its kind, and a model for all later medical scientists. At the time Lind was a surgeon in H.M.S. *Salisbury* cruising in the English Channel. But let Lind speak for himself:

> On the 20th of May 1747, I took twelve patients in the scurvy, on board the Salisbury at sea. Their cases were as similar as I could have them. They all in general had putrid gums, the spots and lassitude, with weakness of their knees. They lay together in one place, being a proper apartment for the sick in the fore-hold; and had one diet common to all, viz. water-gruel sweetened with sugar in the morning; fresh mutton-broth often

* *Lind's Treatise on Scurvy*: A Bicentenary Volume with additional notes, edited by C. P. Stewart and Douglas Guthrie; published for the Edinburgh University Press by Oliver and Boyd, 45*s*.

times for dinner; at other times puddings, boiled biscuit with sugar, &c.; and for supper, barley and raisins, rice and currants, sago and wine, or the like. Two of these were ordered each a quart of cyder a-day. Two others took twenty-five gutts of elixir vitriol three times a-day, upon an empty stomach. . . . Two others took two spoonsful of vinegar three times a-day, upon an empty stomach; having their gruels and their other food well acidulated with it, as also the gargle for their mouth). Two of the worst patients . . . were put under a course of sea-water. Of this they drank half a pint every day, and sometimes more or less as it operated, by way of gentle physic. Two others had each two oranges and one lemon given them every day. These they eat with greediness, at different times, upon an empty stomach. They continued but six days under this course, having consumed the quantity that could be spared. The two remaining patients, took the bigness of a nutmeg three times a-day, of an electuary recommended by an hospital-surgeon, made of garlic, mustard-seed, *rad. raphan*, balsam of Peru, and gum myrrh.

The consequence was, that the most sudden and visible good effects were perceived from the use of the oranges and lemons; one of those who had taken them, being at the end of six days fit for duty. The other was the best recovered of any in his condition; and being now deemed pretty well, was appointed nurse to the rest of the sick.

The experiment was completely successful: Lind had proved that fresh food, especially vegetables and fruit, rapidly cured scurvy. *In particular he recommended oranges, lemons and water cress, all of which we now know are rich in vitamin C.* In addition, Lind's experiment had shown how useless and even dangerous were many of the popular treatments of the day.

In the last two centuries, but more especially in the last forty years, the matter has been carried further than Lind possibly could have done. The 'active principle' or 'vitamin' in oranges has been extracted, identified chemically, and synthesised; you can now buy over the chemist's counter, tablets of pure vitamin C (ascorbic acid) which has been prepared synthetically. But still the work that Lind started is not finished.

Two questions settled only in the last few years were whether a diet, good in *all* respects save the absence of ascorbic acid, produced scurvy, and whether ascorbic acid *alone* can then cure the disease. At the Edinburgh Conference, Dr. Crandon, a young American surgeon and nutritionist, described an experiment in which he induced scurvy in himself in order to answer these questions. Realising that he could settle the matter by studying 'natural' cases of scurvy (which are very rare anyway), Crandon took the courageous course of living on a diet which was adequate in every way, and included all the vitamins with the sole exception of ascorbic acid. After six months the typical symptoms of scurvy had developed; when he had reached that condition he found that a deliberately self-inflicted wound failed to heal. Crandon was now dangerously ill, but after several doses of ascorbic acid he recovered almost immediately. In further work he was able to show the enormous importance of an adequate supply of vitamin C before and after surgical operations.

Dr. Crandon also reminded his audience of the fatal attempt to investigate the problem which was made, nearly 200 years ago, by a young graduate of Glasgow University, William Stark. After reading Lind's *Treatise*, Stark decided that the only way to prove his ideas about nutrition was by a direct experiment on himself. He ate a diet consisting literally of bread and water, with no fruit or vegetable. He began to lose weight and felt ill, his gums became spongy and began to bleed. At first Stark did not realise he was developing scurvy. He became desperately ill, and in 1770, in his thirtieth year, William Stark died of the disease which he had induced in himself.

Crandon's experiment was not absolutely conclusive in that the question could still be asked, Can the results of his one experiment on one human being be reproduced? This was soon settled when ten volunteers, in Sheffield, underwent the same ordeal. This wider experiment was the subject of another paper delivered to the conference, by Professor H. A. Krebs of the Department of Biochemistry at Sheffield University. The experiment took place during the last war when these volunteers, all conscientious objectors, risked their lives by living on a scurvy-producing diet just as Crandon did. In time the symptoms of the disease became perceptible, and in some cases there were clinical signs of severe scurvy. But again the proper treatment restored them to normal health within a matter of several days. The Sheffield experiment confirmed Crandon's experiment, but it was also of great importance during the war since it gave the medical scientists valuable information on the length of time it took for scurvy to appear, and how long a patient took to recover. It had the other important result of demonstrating that the ordinary diet of the British people was adequate. The only class of the population that might suffer was the infant under six months who was fed on bottle or dried milk. Such milk is lacking in vitamin C which is destroyed by heat during preparation. Indeed Dr. Van Eekelen spoke at Edinburgh of the difficulties experienced in Holland during the last war when no citrus fruits were available, and certain signs of scurvy became apparent in young infants. Again the administration of synthetic vitamin C or of rose-hip syrup solved the problem. It is for the same reason that Britain's Ministry of Food provide orange juice for babies and young children.

The Lind Oration was delivered by Surgeon Vice-Admiral Sir Sheldon Francis Dudley, Medical Director-General of the Royal Navy during the last war, at a special graduation ceremony in the Upper Library of Edinburgh University. In his speech he mentioned how he had spent over forty years as a doctor in the Royal Navy, part of that time in the Royal Naval Hospital at Haslar where Lind was chief physician for twenty-five years. Sir Sheldon Dudley paid tribute to Ling's versatility, especially in connexion with his three great classic works, respectively dealing with Scurvy, Hygiene and Tropical Medicine. It was mainly through Lind's work that both scurvy and typhus were banished from the Navy, and Sir Sheldon stated that he had never witnessed a seaman suffer from either of these dreadful diseases. There was no doubt that Lind's discovery had effectively doubled the strength of the Navy, for previously fleets had to be relieved every ten weeks so that scurvy-stricken ships could return to base for rehabilitation. This was at a time when it was necessary to retain the command of the sea. "It was no idle fancy", said Sir Sheldon, "to assert that Lind, as much as Nelson, broke the power of Napoleon." He also mentioned that Lind was the first hygienist to point out that ships were

relatively free from tropical diseases. Sailors who slept in their ships remained free from disease while those ashore mostly contacted the fever, the reason being that insect carriers of disease can seldom travel to a ship which is lying half a mile from the shore to windward of any native village where malaria and other tropical diseases are prevalent. In the last war, this empirical observation of Lind was tested experimentally. A secret naval base was being constructed on a malaria-ridden tropical island. About half the men working on this base lived in huts on the beach, and they were continuously sick with malaria. When reinforcements arrived they were housed in an old hulk lying half a mile off shore. Among the 400 who remained on this hulk between dusk and dawn not a single man suffered from malaria during their eighteen months' residence aboard. When the war was carried into the Pacific Ocean the Americans took the lesson to heart and used a fleet of specially designed and air-conditioned hospital ships to prove Lind's assertion that ships were the best hospitals possible for combined military operations.

Now one limitation which held up for more than 150 years the study of the characteristics of scurvy as a disease was that man seemed to be the only animal, besides the primates, in which the disease occurred. But about forty years ago it was discovered, more or less accidentally, that the guinea-pig is also liable to scurvy. Experiments with guinea-pigs showed that vitamin C deficiency produces changes in the connective tissues which act as a kind of cement to hold together the cells in all organs. As a result of loss of collagen from the connective tissues the cells which form the walls of the capillary blood vessels fail to stick together, and so the familiar haemorrhages arise: there is also defective formation of dentine in the teeth, and bones become deformed, all three lesions being due to the failure of the supply of collagen to maintain connective tissue and intercellular cement. Lind himself showed that in cases of scurvy this formation was defective. It is now known that vitamin C is closely connected with the activity of certain hormones, e.g. in the adrenal gland. It has also been found that there is a connexion with certain enzymes which control the rate of chemical changes in the body. Indeed many chemists believe that the peculiar chemical properties of ascorbic acid, in reacting with air, hold the key to its biological importance.

Experiments with human volunteers have shown that daily doses of 5 milligrams of ascorbic acid will prevent scurvy and 10 milligrams per day will cure it. But as one individual differs from another in his requirements, some margin of safety is necessary. Thus each individual should receive a supply of the vitamin in excess of the amount required by the controlled patient in a limited experiment. If the diet is adequate, of course, no daily dose of the vitamin is necessary, but it can be useful in an emergency. Arctic explorers, for example, must consider carefully the weight of food they carry, but half an ounce of ascorbic acid would protect a man for a year: a hundredweight, dropped by parachute, would be sufficient for a complete brigade of a besieged army.

Lind knew that fresh fruit and vegetables were the most efficient antiscorbutics, and this has been verified by medical scientists today. Here is a list of the ascorbic acid content of some antiscorbutic remedies described by Lind.

JAMES LIND
(Courtesy, Medical Director-General, Royal Navy.)

Milligrams of ascorbic acid per 100 grammes (about 3 ounces)			
Orange juice	50	Scurvy-grass (*Cochlearia officinalis*)	50
Lemon juice	40	Pine needles (whole)	150
Lime juice	20	Sauerkraut	10
Blackcurrant	180	Malt	0 to trace
Gooseberry	30	Milk	0–1·0
Parsley	140	Wine, beer, cider	0
Watercress	50		
Onion (raw)	10		

It is interesting to note from these figures that Lind was correct in preferring oranges to lemons as the best fruit for a ship's crew. His recommendation that cress should be grown in boxes on the ramparts of a besieged town was not always known by prisoners in the last war, although certain Arctic explorers during the 19th century had made good use of this method of providing an antiscorbutic supply of food. Yet it is tragic to think that scurvy was mainly, if indirectly, responsible for the death of Scott and his colleagues who might have returned safely from the South Pole.

Lind is first remembered for his famous *Treatise*, but his other books on Hygiene and Tropical Medicine were also of outstanding importance and led to a revolution in conditions at sea.

He was responsible, more than any other man, for the improved conditions of our seamen, for methods of improving the storage and quality of foods, for producing adequate supplies of drinking water (by filtration and distillation), for ventilation in ships, and for improving the morale of the men. It is little wonder that the Royal Navy honour James Lind as the 'Father of Nautical Medicine'.

THE BOOKSHELF

Weather Inference for Beginners by D. J. Holland (*London, Cambridge University Press, 1953, 195 pp., 30s.*)

The words 'for beginners' when appearing on the title page of a book are crucial ones. Not merely must such a book be good—it must also be good for beginners. How does the book stand up under this criterion?

The author's style is very suitable for racy exposition of a praiseworthily, unorthodox kind. He writes fluently and clearly with apposite and often new instances. He speaks from personal and enthusiastic experience—and uses his own observations as a basis of discussion throughout the book—although perhaps not enough to justify the space he has allotted them. He writes as a forecaster of some experience and knowledge, and most of the subject matter is technically accurate (which is more than can be said for many such texts for beginners!).

Is the book, then, a good one for beginners? It depends on the beginner. To a semi-beginner the verve and ingenuity of the writer might well compensate for any faults or obscurities. If the reader knows a bit of mathematics and physics already he will manage to take in enough of the book to give him many interesting facts about weather. But without this preliminary knowledge, he could get lost. A book which endeavours to cover in 196 pages practically the whole of physical and synoptic meteorology (with practical and discursive examples plus advice on forecasting, briefing and even 'debriefing'), is bound at times to suffer from meteorological indigestion. This tendency is aggravated by a plethora of abbreviations. A meteorologist might recognise u.a.t. almost at a glance, a second's thought translates w.p.t. and r.h., but the reviewer has to record that he boggled at s.m.c., and many others.

A few more specific points are worth noting. The expression 'weather type' is used frequently but not in the commonly accepted sense of a kind of pressure distribution. The section on 'air hydrodynamics' goes into too much advanced detail. The synoptic charts are small, and (like the Meteorological Office charts from which they are copied) badly drawn. They fail to demonstrate the essential continuity of synoptic situations and hence tend to encourage a view of the weather as static rather than ever changing.

A chapter on upper winds and forecasting has not a single diagram; and this exemplifies one of the major faults of the book. The writer relies too much on his considerable powers of word-painting to overcome a lack of diagrams. If he had been satisfied with fewer facts and more exposition of them, a pleasantly readable book for semi-beginners might have been turned into an invaluable book for all beginners.

G. L. HOGBEN

Lecture Notes on the Use of the Microscope by R. Barer (*Blackwell Scientific Publications, Oxford, 1953, 74 pp., 8 figs., 6s.*)

Few students of biology receive from their teachers adequate instructions in the use of the microscope—an unfortunate circumstance that tends to perpetuate itself as students in their turn become teachers. Nor does the average student gain much from the typical manual of microscopy which is far too long for the time he can afford to spend in studying it, far too detailed for his elementary requirements, and far too dear for his slender resources. This little book therefore most admirably fills a dual need: it provides a basis for a series of lectures by the teacher or, if the teacher has no time to spare, it is short enough, simple enough and cheap enough to be bought and read with profit by the student.

The author restricts himself to the basic knowledge and skill needed for the proper use and care of a student-type microscope. Perhaps there is room here for debate but this reviewer finds himself willing to second most of the author's proposals. The specification of the instrument around which the book is written is superior to that of most student microscopes and one feels that some of the better-known sacrifices on the altar of cheapness might have earned a word of disapproval. The tricky business of correcting for coverglass thickness is wisely omitted since few student microscopes are fitted with a draw-tube. In any event the reward in terms of resolution obtainable from the grade of high-power dry objective usually encountered is not worth the trouble of adjusting a draw-tube if one is present. At the end of the book, however, Mr. Barer thoughtfully provides an appendix on Köhler illumination for the benefit of the advanced student: again one cannot disagree with his choice, Köhler being easier to obtain and more effective with an electric source than true critical illumination.

After an excellent pair of chapters on the theory of microscopy, the author deals with the usual types of objective and eyepiece and with the selection of suitable lens combinations. In this connexion he recommends that the total magnification should not be less than 250 times nor more than 1000 times the numerical aperture of the objective. It might have been made clear that these limits, particularly the lower one, need not be applied too strictly. One can visualise the keen student who, requiring a magnification of × 60, demands a × 12 eyepiece and a 32-mm. objective rather than infringe the rule by using the × 6 eyepiece and 16-mm. objective with which his microscope is fitted and which, in the event, would serve him better. At the other end of the scale the same student might be led to 'over-eyepiece' a 4-mm. objective instead of using a 2-mm. with a low-power eyepiece. To be fair, it must be recorded that Mr. Barer warns that only a very good objective will stand up to a × 20 eyepiece; although he might have gone further to say that the average 'student-quality' 4-mm. achromat of N.A. about 0·65 is not at all happy with an eyepiece of greater magnification than × 12. The advanced student will seldom need a total magnification of more than × 1000, which is well within the stated limits for a 2-mm. objective. If, however, he should find himself needing all the resolving power he can get he should be told that, given a good objective, he will not lose resolution by eyepiecing up to × 15 or even × 20 and that he may gain in comfort. His choice of eyepiece may indeed be governed more by the delicacy of his fine focusing control than by optical factors.

The practical instructions which follow are models of their kind, insisting on the proper use of the condenser and on the importance of inspecting the back lens of the objective while adjusting the substage iris diaphragm. The usual instruction to rack upwards into focus is given, but it is perhaps a counsel of perfection to extend this method to oil-immersion objectives. Indeed one would have thought that racking down such an objective beyond its working distance would materially increase the chances of contact between the front lens and the cover-glass. At the end of the book there is a second appendix containing experiments with the microscope, which are well worth doing as they impress on the student the importance of some of the routine operations he is elsewhere told to carry out.

Necessarily much has to be omitted from a book of this size; the reader should not expect to find anything about photomicrography, ultraviolet or electron microscopy. There is no more than a passing mention of dark-ground illumination and the phase-contrast microscope. There is, however, a short bibliography which will direct him to sources of information on these and other more specialised branches of the subject.

R. P. HILL

Far and Near

Night Sky in August

The Moon.—New moon occurs on August 9d 16h 10m, U.T., and full moon on August 24d 20h 21m. The following conjunctions with the moon take place:

August					
5d 03h	Jupiter in conjunction with the moon		Jupiter	4°	S.
6d 02h	Venus	,,	Venus	5°	S.
8d 02h	Mercury	,,	Mercury	3°	S.
15d 11h	Saturn	,,	Saturn	8°	N.

In addition to these conjunctions with the moon, Mercury is in conjunction with Mars on August 23d 14h, Mercury being 0·1° S.

The Planets.—Mercury is too close to the sun in the early part of the month for observation, but towards the middle of the

month it rises about 1½ hours before the sun and can be seen in the eastern sky for a short period before sunrise; its stellar magnitude is then about 0·1. At the end of the month it rises about 40 minutes before the sun and will not be observable. Venus is a morning star, rising at 1h 10m, 1h 20m, and 1h 50m, on August 1, 15, and 31, respectively; its stellar magnitude is −3·5 during most of the month and the visible portion of its illuminated disk varies from 0·67 to 0·78. Mars rises about 3h 40m throughout the month, which is less than an hour before sunrise at the beginning of August so that the planet could not be easily observed then, and an hour before sunrise at the middle, and over 1½ hours at the end of the month. The planet will not, therefore, be conspicuous during the whole of August and cannot be seen for long before sunrise. Jupiter rises at 0h 30m, 23h 40m, and 22h 50m on August 1, 15, and 31, respectively; towards the middle and end of the month it will be seen a little north of ζ Tauri which it gradually approaches in its easterly movement. Jupiter is brighter than the star and has a stellar magnitude −1·8 in the last two weeks of August. Saturn sets at 22h 15m, 21h 20m, and 20h 20m on August 1, 15, and 31, respectively; during the month it lies about midway between α and ζ Virginis and a little east of θ Virginis.

On August 9 there is a partial eclipse of the sun; only a third of the sun's diameter is obscured by the moon, and the eclipse is invisible in Britain.

The Perseid meteor shower attains a maximum about August 10–12 and there will be no moonlight to spoil observations of these meteors.

The British Instrument Industries Exhibition

Many new and interesting scientific instruments were seen at the second of the British Instrument Industries exhibitions held at Olympia from 30 June to 11 July.

Of particular interest were several instruments which make use of radioactive materials in a novel manner. One of these is an ionisation anemometer for measuring slow air currents, which is so sensitive that it will record the current of hot air produced by the flame of a cigarette lighter held a foot away. It consists of two spherical wire grids in the centre of which is a cube containing a radioactive element. The outer wire grid is purely protective, but when the machine is in operation, a cloud of atomic particles is formed round the inner grid through which an electric current passes. The disturbance of this cloud by an air current causes a drop in the voltage of the current, and the degree of this change gives a measure of the wind speed. This instrument, which was originally designed for recording air currents in the magazines of warships, is now being developed for use in the coal mines and in other industries where slow air currents may prove dangerous as carriers of dust or gas.

Among the instruments on the Ministry of Supply stand was a detector that enables prospectors to locate uranium ore deposits from low-flying aircraft. Gamma radiation from the uranium causes scintillations in a large sodium iodide crystal and these are registered on sensitised paper. The Ministry also showed a detector for tracking down radioactive minerals in deep boreholes; this comprises a Geiger counter and amplifier enclosed in a steel cylinder 1⅜ in. in diameter and 2 ft. 7 in. long, which can be lowered to a depth of 1500 ft. from a surface winch.

Notable amongst a large number of *p*H meters of various kinds, was an instrument for automatically undertaking titrations, surely one of the most oft-repeated chores in chemical laboratories. The apparatus consists of a graduated glass burette which fills to a constant level, at the bottom of which is a special tap which is controlled by a solenoid. An electrode connected with the control unit and an automatic storing device are placed in the unknown solution which is to be titrated below the burette. The operator sets the dial of the control unit at the *p*H at which the process is complete, and then switches on. The solution then flows from the burette until a 'safe' previously fixed point has been reached, when the tap is automatically turned to the slow position. The solution now leaves the burette drop by drop until the end-point is reached, when the tap is automatically closed. Several titrations can be controlled simultaneously by the same machine.

Of the ultrasonic instruments on show, Mullard's ultrasonic concrete tester was perhaps the most interesting. Built to the design of the D.S.I.R.'s Road Research Laboratories, it is designed to serve a triple function. It can be used to test the quality of concrete both in test samples in the laboratory, and in the completed structural member. It can also be used for testing the concrete during the hardening process: a point of some importance in the manufacture of pre-stressed concrete since this can be done without releasing the tension on the stressing wires. The measurement is undertaken by electrically timing the passage of a short series of ultrasonic vibrations which are transmitted through the concrete.

Another machine produced by the same firm generates vibrations of ultrasonic frequency in a drilling tip. When carbide abrasive is fed to this tip it can be used to drill holes in brittle metals, gems and ceramics, and other materials difficult to penetrate by conventional methods. The ultrasonic drill does its job rapidly: for example, using a 40-watt electrical drive power, a ¼-in. square hole can be drilled ⅛ in. deep in glass in about one minute.

An important research tool developed for work on a specific problem is the 3D film camera, developed by the British Iron and Steel Research Association, which will photograph the movements of particles in the combustion zone of a furnace at a speed of 3000 frames a second. Ancillary equipment consisting of a special arrangement of sextant mirrors enables these movements to be accurately plotted in the form of a 3-dimensional graph. One interesting feature of this apparatus is the fact that the use of the stereoscopic camera enables an observer looking at the film (not plotting it on the graph) to see the particle movement much more accurately than is normally possible with the naked eye. This apparatus makes it possible to measure the movement of particles with considerable accuracy.

One noteworthy feature of the exhibition was the number of exhibits which could be used equally well in both the research laboratory and as control mechanisms in manufacturing processes—a fact which reflects the immensity of the impact of science on modern industry.

OUR COVER PICTURE: The flagship of the "Discovery" class Viscounts. The Vickers Viscount 700, the world's first turboprop airliner to come into service, flies on B.E.A. routes and has been ordered by four other airlines. It is powered by a 1400 h.p. Dart engine, and carries 47 passengers; a 1540 h.p. version will be used in the Viscount 800, designed to carry 82 passengers.

A Revolutionary Aeroplane

A model of an aircraft designed to rise vertically and fly faster than a helicopter is being tested at the field laboratory of the National Advisory Committee for Aeronautics, Langley Field, Virginia. The plane is operated by remote control. It is equipped with four wings which can be curved to deflect the airflow from the propellers straight downwards. This forces the plane up. After the take-off the wings can be straightened to guide the airflow over the wings and rearward, as in a conventional type plane.

Labour Party favours Technological University

The Labour Party favours the immediate setting up of a technological university. This is stated in the recent policy statement (*Challenge to Britain*).

Centenary of Kew Herbarium

Kew Herbarium is a hundred years old. The nucleus from which it started was the collection of Dr. W. Arnold Bromfield, which was presented to Kew in 1853, twelve years after the Royal Botanic Gardens became a public institution. The herbarium's first keeper was Prof. Daniel Oliver, of University College, London, and the present occupant of this post is Dr. W. B. Turrill.

Oxygen in the Conquest of Everest

The summit of Everest, 29,002 feet high, was scaled on 29 May by E. P. Hillary and the Sherpa Tensing Bhutia of the British Expedition. Among the scientific equipment which proved of vital importance in this, the first successful attempt on Everest, was the oxygen apparatus. This was in frequent use at heights from 19,000 ft. upwards.

The expedition had two types of oxygen equipment. In the open-circuit set (used on the final ascent) there was sufficient oxygen to last 10 hours when used at the rate of 4 litres a minute. The closed-circuit set, which included two canisters of soda lime to absorb exhaled carbon dioxide, rendered the user quite independent of atmospheric oxygen.

Sir Henry Wellcome (1853–1936)

The Wellcome Foundation is celebrating the centenary of Sir Henry Solomon Wellcome (1853–1936) with an exhibition, which was opened by the American scientific attaché in London on 8 July.

Wellcome was born in Wisconsin, and developed his interest in pharmacy under the tutelage of W. W. Mayo. At the age of 27 he came to Britain and in partnership with S. M. Burroughs, another American, he started the famous drug firm. For their tablets of compressed drugs they invented the trade mark 'Tabloid', a word which has become part of the English language—in spite of the insistence of the firm's legal department that the word must never be spelt except with a capital T!

Wellcome founded the Physiological Research Laboratories, the Chemical Research Laboratories, the Research Institution, the Museum of Medical Science, and the Historical Medical Museum which bear his name.

For his services to science, Wellcome was elected an F.R.S. in 1932, and was knighted in the same year.

Sir Flinders Petrie (1853–1942): A Pioneer Archaeologist

On 17 June, University College, London, celebrated the centenary of the birth of Sir William Matthew Flinders Petrie, founder of modern Egyptological studies, who died in Palestine on 29 July 1942.

Petrie started his lifelong career of exploration in Egypt in 1880 with an examination of the pyramids of Giza, and three years later he became field director of the Egypt Exploration Fund, a recently formed organisation for Egyptological research. The Edwards Chair of Egyptology was founded at University College, London, in 1894 and Petrie was appointed as the first professor of Egyptology in this country. For the next forty years, Petrie excavated each winter in Egypt and spent his summers at University College teaching and publishing the results of his discoveries and research. Over a hundred books came from his pen. Our knowledge of Ancient Egypt has greatly advanced since his day.

The Spectrograph and the Locomotive Engineer

Speaking at the Summer Convention of the Institute of Physics at Bournemouth, Dr. A. C. G. Menzies of Hilger & Watts stressed the growing importance of spectrographic analysis in all branches of engineering, particularly in anticipating failures. One particularly interesting application he mentioned was the use of the spectrograph in routine checking of diesel locomotives on American railways. The sudden increase of metallic or other impurities in the crank-case oil would indicate a probable failure many weeks before it actually occurred, and the nature of the impurity gave a reliable clue to the cause of failure.

Careers in Chemical Engineering

A well-illustrated brochure with the title *Careers in Chemical Engineering* has just been published by the Institution of Chemical Engineers (56 Victoria St., London, S.W.1). It seems in every way likely to achieve the purpose for which it was designed—to interest more students in the career prospects offered by the profession of chemical engineering. Interested career masters and science masters are invited to address requests for copies direct to the Institution's general secretary, mentioning DISCOVERY by name.

Nuclear Physics for Engineering Students

A course in 'nuclear energy' has been started at Queen Mary College, University of London, for third-year engineering students. On 23 June the college held a ceremony to inaugurate its Nuclear Particle Laboratory. Its research equipment includes a 1-million-volt electrostatic generator, while a 1-million-volt impulse generator is nearing completion. There is also a 5 MeV betatron which can be used to give short X-ray impulses at higher voltages.

The lectures in this course are based mainly on recently declassified information about nuclear reactor design, and also on the general aspects of nuclear physics as they are related to engineering.

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